

PROJECTS THEORY APPLICATIONS CIRCUITS TECHNOLOGY

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March 2010

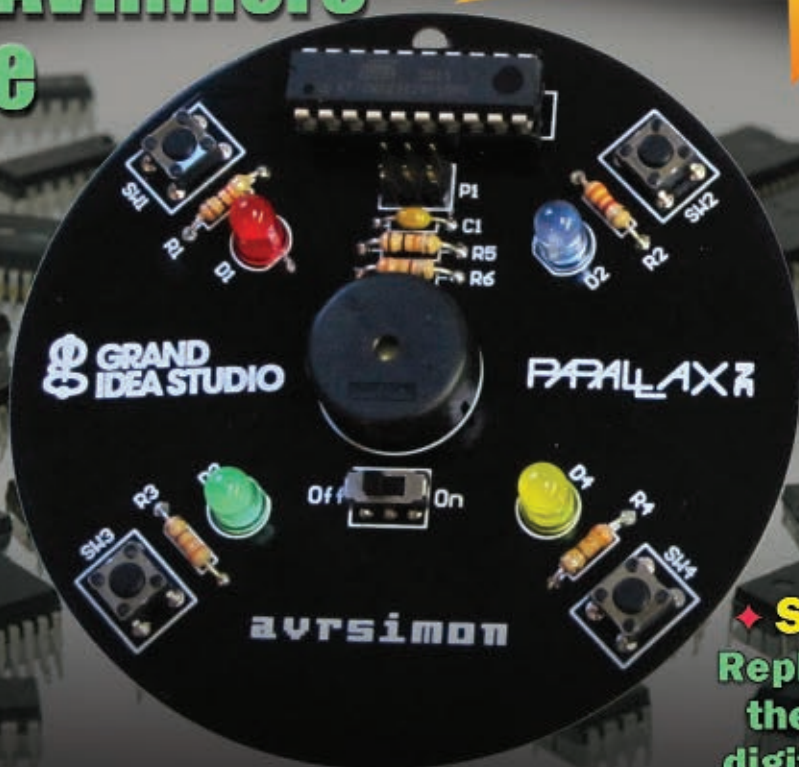
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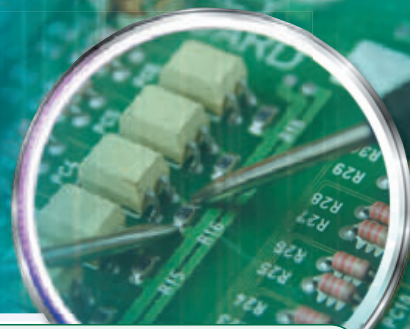
Whether you're looking for new ways to explore interactive art, or want a tutorial on physical computing, the resources are out there. Find out how electronics fit with your passions, and let your geek shine too.



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after engine modifications, prevent engine boost cuts; or alter sensor signals for improved drivability. Requires hand controller for programming, RS232 cable and a suitable input signal. Kit includes PCB, case and electronic components.



NEW TO EPE

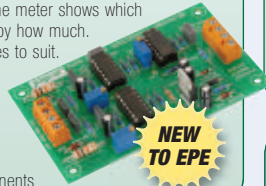
Recommended with this kit:
Hand Controller Cat. KC-5386 \$39.50
RS232 Cable Cat. WC-7502 \$7.00



MARINE ENGINE SPEED EQUALIZER KIT

KC-5488 \$23.25 plus postage & packing

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NEW TO EPE

- 12VDC
- PCB and specified components

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includes solder mask & overlay PCB, programmed micro and specified electronic components. Case, heatsink and battery holder not included.

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KC-5479 \$46.50 plus postage & packing

Prolongs the life of your lead acid batteries. Like the original 2005 project, this circuit produces short high level bursts of energy to reverse the sulfation effect. The battery condition checker is no longer included and the circuit has been updated and revamped to provide more reliable, long-term operation. It still includes test points for a DMM and binding posts for a battery charger. Not recommended for use with gel batteries

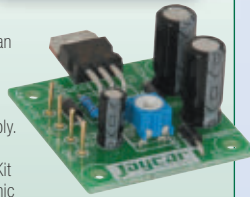


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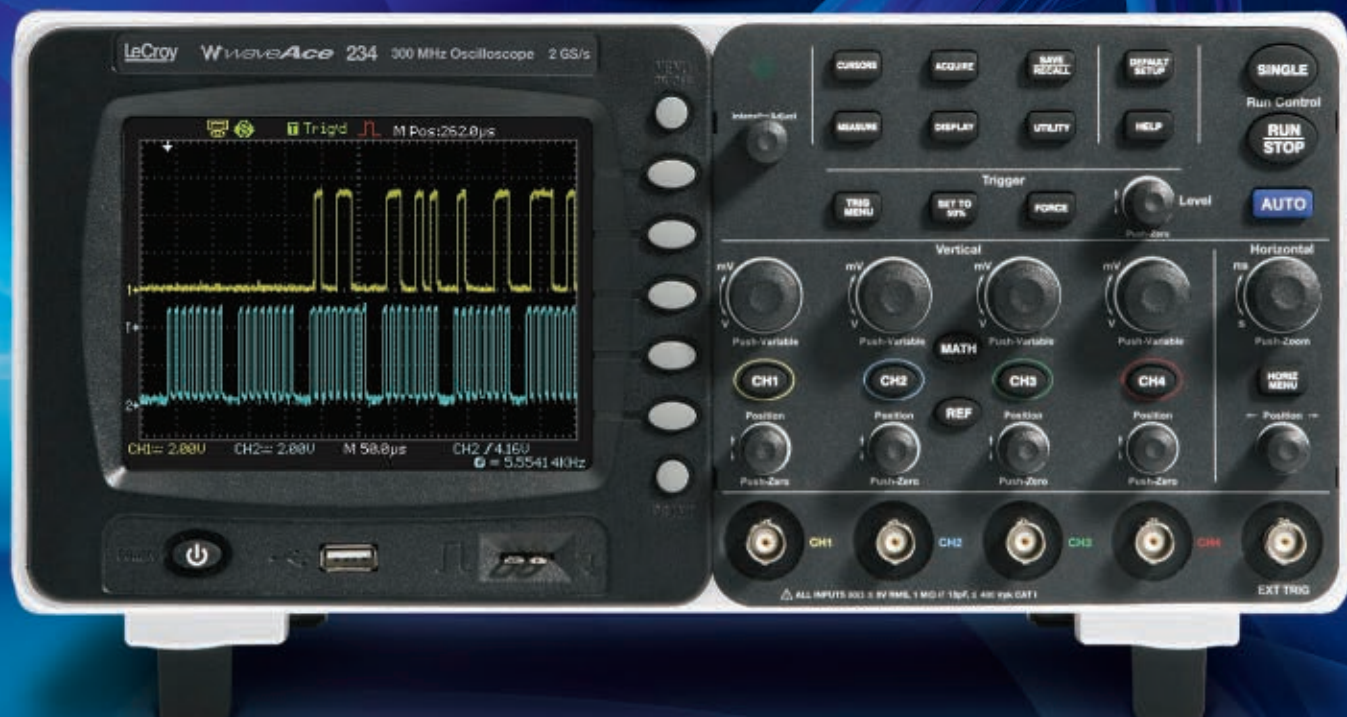
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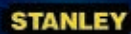
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Projects & Features

32 Make the SmartStat-Plus

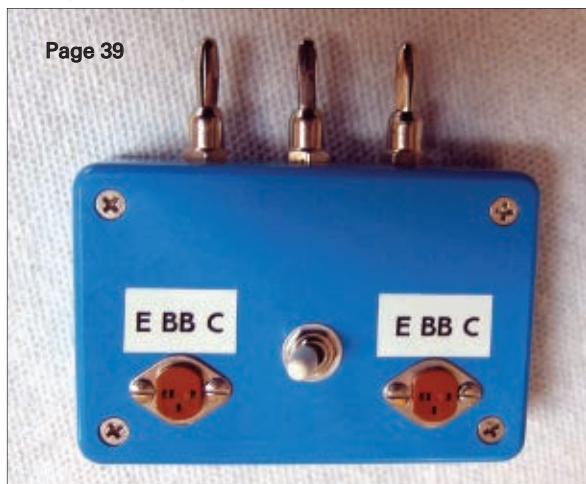
This MCU-controlled digital thermostat will monitor your furnace and AC air filter, and let you know if there's a problem.

■ By Thomas R. Fox

39 Build Your Own Electronics Test Fixtures

Setting up test fixtures for your components will help you sort through your junk box quickly and speed your projects along.

■ By W. Hartley Roberts



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42 The Projects of Prototype This!

Take a closer look at the electronic aspects of the different builds from the popular Discovery Channel show Prototype This! The first project is avrsimon — a modernized version of the popular memory game.

■ With Joe Grand

NEW!

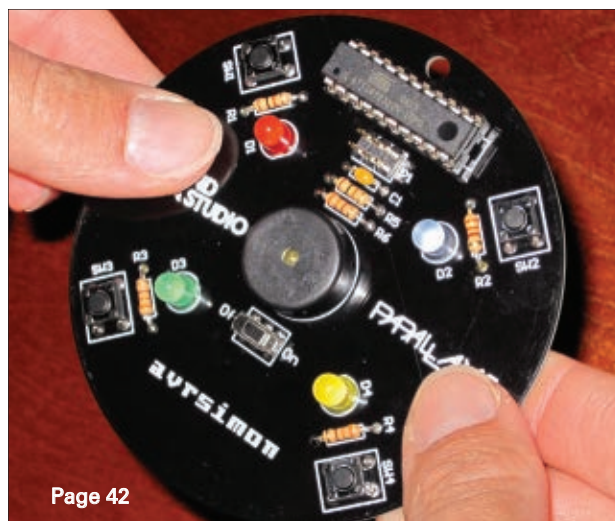
48 Experiments with Alternative Energy

Learn the fundamentals of renewable energy through this educational series. This month: Introducing the WindPitch WindTurbine.

■ By John Gavlik

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Events, Advances, and News

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Adventures in Propeller Programming

If you've been waiting for BASIC to play with the Propeller, your wait is over!

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Reader Questions Answered Here

A doorbell light, soldering iron timer, revisiting the countdown timer and large clock, plus more.

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Programming • Hardware • Projects

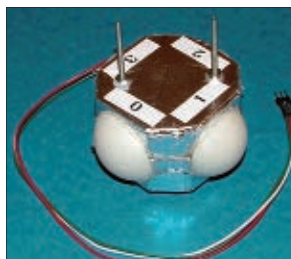
Serial Communications Part 3. We'll build an Arduino voltmeter and meet the FT232R.



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Advanced Techniques for Design Engineers

Making a mesh of things.



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Sun sensor for data collection.

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SSH ENCRYPTED SERIAL TO ETHERNET SOLUTIONS

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by Bryan Bergeron, Editor

DEVELOPING PERSPECTIVES

Going, going, gone ...

My local electronics parts supplier finally succumbed to economic pressure and replaced its modest parts inventory with cell phone batteries and accessories. It's a sound business decision for the owner, but my prototyping costs just doubled because small orders from online suppliers are a costly affair. As I've mentioned in this column, it looks as though kits are the wave of the future of electronics experimentation — unless you're good at teardowns.

Fortunately, there are several viable suppliers — including advertisers in this magazine — offering quality kits at affordable prices. Kits offer real savings in both time and money. If you turn to Digi-Key or other major parts suppliers, you won't get a price break on a handful of components, and if you have to reorder a part you forgot on your first order, shipping costs can total more than the components.

Similarly, while I use online printed circuit board manufacturing services, custom boards are an increasingly expensive option. I've been using the all-in-one prototyping boards offered by several suppliers when possible. Some of the oddest and most useful boards are offered by SparkFun Electronics (www.sparkfun.com). I especially like their triangular 3D protoboards for robotics work.

Where the domestic kits market is apparently alive and well, I like to sample the offerings of overseas kit makers. One of my favorite kit suppliers is AnalogMetric (www.AnalogMetric.com), a Hong Kong-based firm that caters to the high-end DIY audio market. I've purchased several tube audio amp kits in the past with great results. My most recent purchase was a TDA1541A digital-to-analog (DAC) kit that takes a digital audio signal from a CD player, computer, or music synthesizer, and outputs a clean analog audio signal.

The unpopulated 2.5 mm

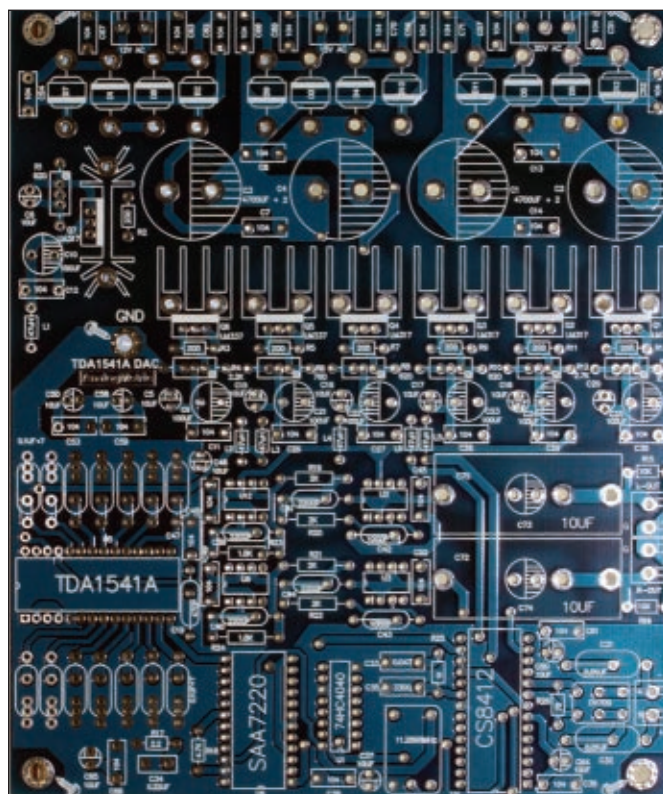
PCB for the DAC kit is shown in **Figure 1**. As you can see, the labeling on the bullet-proof board is so extensive that kit building is virtually paint-by-numbers. It took an afternoon for me to assemble the kit and a few minutes for setup. Performance of the 16-bit DAC is comparable to my commercial recording gear, and the board layout is so clean that it's a shame to hide it in an aluminum enclosure.

AnalogMetric kits — which range in price from \$15 to well over \$1,000 — aren't for novice kit builders. While the boards can probably handle a few failed attempts at soldering, there is little handholding for the construction and testing process. It's assumed that you can read a schematic, identify components, know when to observe component polarity, and know how to connect a power transformer to the line and the circuit board.

If you're uncertain about the difficulty level of a particular kit, take a look at the photographs, full schematics, and documentation available on the AnalogMetric website. With many of the kits, you can either order an upgraded kit or order the base kit and add your own upgrades. For example, I ordered the basic DAC kit with an NE5534 op-amp, and replaced the amp with an AD797AN op-amp that I had purchased for another project.

The main downsides of dealing with an offshore company are the postage and shipping delay. I avoid the postage penalty with AnalogMetric by ordering bare kits without a power transformer. If you don't have supply transformers in your junk box, then you should consider their toroidal transformers. They're compact, well built, and — for pro audio components — relatively affordable.

Another of my favorite offshore kit suppliers is Oatley Electronics (www.oatleyelectronics.com), located down under. Oatley kits are great for beginners of any age, with starter kits such as simple LED illuminators. They also



make serious (but easy to build) and affordable kits for enthusiasts. For example, last year I wrote about Oatley's sub-miniature tube-type headphone amplifier which I modified for use with my electric guitar.

I recently purchased the upgraded headphone amplifier kit — the K272 — which uses a pair of JAN6418 sub-miniature pentodes to provide stereo amplification. While the circuit diagram is not posted online, the circuit board layout and parts list is available. This should be enough information for you to decide whether it's more economical to order the kit and pay postage from Australia or scrounge around for local parts. Regardless of cost, I'm hooked on their tube amplifiers.

While kits are a quick fix for the increasing scarcity of affordable components, for the long-run, I'm a big believer in teardowns. Not only are thoughtful teardowns a source of components, but they can provide insight into how devices are constructed. It's one thing to open a shrink-wrapped bag of components and another to carefully remove components from a circuit board. By examining components in context, you can see how issues such as heat dissipation, fusing, component bypassing, and component density are addressed.

If you're fortunate enough to live near a parts supplier, consider yourself lucky. If not, consider the myriad options available from kit

suppliers just a few keystrokes away. **NV**

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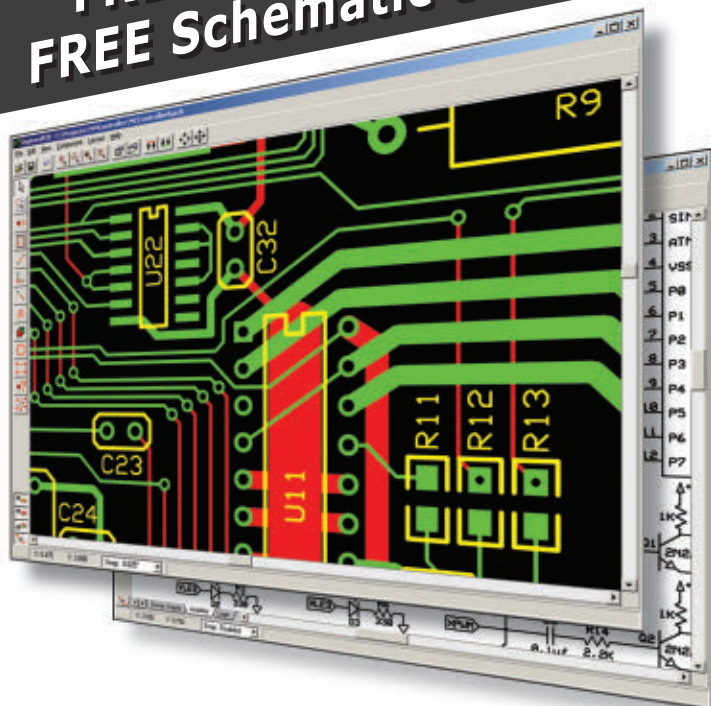
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READER FEEDBACK

BROKEN-IN SPEAKERS DON'T SOUND RIGHT

In reading your article on speaker break-in, I was compelled to write and inform you of a few facts on speakers, wire, etc. First of all, in each of the 45 years I have been an electronic technician — both in civilian life and military — I have run across many selling scams, pitches, etc. This has to be the No. 1 on the list. There is no such thing as breaking in speakers. They are what they will be (either new or used), of course, if they are subject to excessive voltage spikes; this would cause overheating of the voice coil or damage to the cone. In exception to that scenario, the speakers would sound the same across their lifetime. Now, a speaker will deteriorate due to cone aging (mainly foam surround) and this will cause sound problems. As far as wire (cable, power cords, etc.) needing break-in, this is also a bunch of BS. Cable and wire have NO break-in. It is what it is from day one. I also will mention these so-called oxygen free speaker cables ... another bunch of BS. Standard stranded wire of 16-18 gauge is entirely adequate, that is properly terminated with high QUALITY CONNECTORS. Anyone who says different is just trying to sell oats that have been through the horse.

Mike Jobe

Thanks for the note/feedback. I'm right there with you. It's amazing what some dealers try to get away with. But,

as with telemarketing, apparently some people respond to the ads in the audiophile magazines.

Bryan

DOUBLE-SPEAK ON SPEAKERS

I loved your editorial about breaking in speakers and cables. How do we know the breaking in of a speaker does not actually impair the "virgin" fidelity of a freshly manufactured speaker?

Continued on page 77

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■ BY JEFF ECKERT

ADVANCED TECHNOLOGY

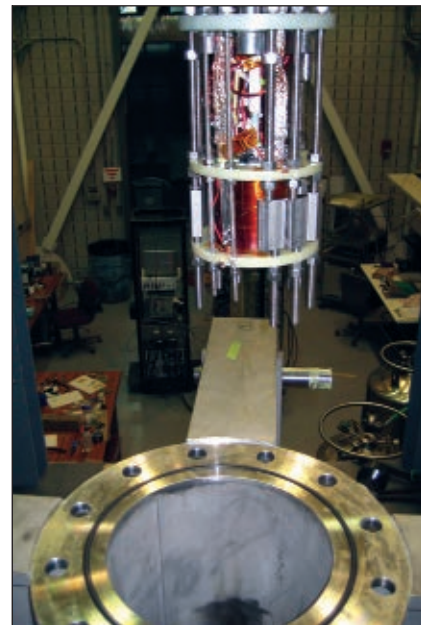
SUPER MAGNET UNDER DEVELOPMENT

We often focus on research that produces the next world's fastest computer, world's fastest robot, and so on. But a bit less celebrated is work being done at the National High Magnetic Field Laboratory (www.magnet.fsu.edu) aimed at building the world's most powerful magnet. The Mag Lab — armed with a \$2 million grant from the National Science Foundation and another \$1 million from Florida State University — is on its way to building a device projected to generate a magnetic field of 32 tesla. To put this in perspective, note that the field strength of the Earth is only somewhere between 30 and 60 T, depending on how close to the poles you measure it; MRI machines create about 1 to 2 T. The key to the new design is a high-temperature superconductor called yttrium barium copper oxide (YBCO).

Being superconductive, the material can function without the friction created in resistive magnets, thereby saving huge amounts of electrical consumption. At the Mag Lab, the average cost to operate a resistive magnet is \$774/hr which is about 40 times as much as a superconducting magnet. In addition, YBCO makes it unnecessary to use expensive cryogenics like liquid helium to maintain superconductivity.

Although it's unlikely that you'll ever find one keeping your refrigerator door closed, the devices — which also

create more stable magnetic fields than resistive magnets — offer plenty of advantages for engineering and research. According to Stephen Julian (a University of Toronto physicist and member of the lab's external advisory board), "This magnet opens up new possibilities for measurements that we have previously only dreamed of. With these new magnets, researchers will be able to stay at these very high magnetic fields for as long as they like. This will dramatically increase the quality of data for many measurements. We can look forward to breakthroughs in biomedical magnetic resonance imaging, studies of protein structure, semiconductor physics, and the physics of metals." ▲



■ A YBCO test coil is lowered into a cryostat for a test at the Mag Lab.



■ Thin crystalline-silicon photovoltaic cells measuring from 14 to 20 micrometers thick and .25 to one millimeter across.

GLITTER POWER

We're not talking about David Bowie or T. Rex here. It's a concept recently revealed by the folks at Sandia National Labs (www.sandia.gov) that could "revolutionize the way solar energy is collected and used." Whereas today's collectors are pieced together from six-inch square wafers, the new design employs fairly common microelectronic and microelectromechanical systems (MEMS) techniques to produce glitter-sized cells that promise to be cheaper to produce, useful in a wider range of applications, and more efficient. A big advantage is that the glitter cells use 100 times less silicon than conventional cells to generate the same amount of electricity which could reduce production costs. Plus, because they can be integrated into things like clothing, you could even end up as a walking battery charger.

According to Sandia field engineer Vipin Gupta, "Photovoltaic modules made from these micro-sized cells for the rooftops of homes and warehouses could have intelligent controls, inverters, and even storage built in at the chip level. Such an integrated module could greatly simplify the cumbersome design, bid, permit, and grid integration process that our solar technical assistance teams see in the field all the time."

COMPUTERS AND NETWORKING

ENTRY-LEVEL SERVER INTRODUCED

If you're in the market for an entry-level enterprise server, Sun Microsystems and Fujitsu have a deal for you. The latest product of their 20-year collaboration is the SPARC Enterprise M3000, described as a single-socket, highly reliable, mission-critical server powered by a quad-core SPARC64 VII processor. The processor runs at 2.75 GHz and offers faster system memory modules to deliver up to 23 percent better performance than the previous generation. Running the Solaris operating system, it is aimed at applications including database maintenance, customer relationship management (CRM), business intelligence and data warehousing (BIDW), and enterprise resource planning (ERP). Sun noted, "In addition, the enhanced SPARC Enterprise M3000 server improves the ratio of energy consumption to application throughput by up to



13 percent compared to the previous version, helping customers further reduce their environmental footprint."

Sun's website shows the base configuration starting at \$14,795 which includes 4 GB of memory, twin 146 GB drives, and a twin-core processor. You'll pay big for accessorizing, though, as the quad-core, 32-GB version comes in at \$38,795. A range of configurations is available. The machine is marketed with both Sun and Fujitsu nameplates, but they are identical inside. For details, see sun.com/sparcenterprise. ▲

GLITTER POWER CONTINUED

It may sound like a challenge to assemble a collector from so many tiny cells, but contemporary pick-and-place assembly equipment can drop up to 130,000 of them onto a substrate's contact points in an hour's time. Given that a collector is likely to use in the neighborhood of 10,000 to 50,000 per square meter, we're in realistic territory. More advanced MEMS techniques could employ self-assembly to further lower costs.

The glitter cells currently operate with 14.9 efficiency which is reasonably competitive with off-the-shelf modules. Sandia reps also noted, "High-voltage output is possible directly from the modules because of the large number of cells in the array. This should reduce costs associated with wiring, due to reduced resistive losses at higher voltages. Other possible applications for the technology include satellites and remote sensing." ▲

DOCK YOUR LAPTOP FOR LESS

At the 2010 International Consumer Electronics Show, Toshiba unveiled a low-end addition to its Wireless and wired Dynadock U family: the Dynadock V. All are USB 2.0 boxes that allow universal connectivity while using your laptop in the office or at a desk at home. The V model is only about half the size of its brothers, so you get a bit more desk space to work with. From a single USB port on your computer, Dynadock provides links to a range of add-on peripherals including an external monitor, keyboard and mouse, printer, router, and so forth. It also features a "sleep-and-charge" port that can power things like cell phones and MP3 players, even when the computer is shut down.

For the asking price of \$119.99, you get the use of four USB ports, Ethernet connectivity, 3.5 mm audio in and out jacks, and a built-in 1920 x 1080 HD video card. Not bad, but one might wonder why anyone would buy this unit when the U box gives you six USB ports, a 7.1-channel cinema surround-sound card, and 1920 x 1200 monitor resolution for another 30 bucks. In any event, all three come with Windows XP, Windows Vista, and Windows 7 drivers. In case you were wondering, the Dynadocks do not provide power to the laptop for operation or battery charging. Details are available at www.dynadock.com. ▲



■ Toshiba's Dynadock V, a new low-end member of the family.

CIRCUITS AND DEVICES

TEMP SENSOR TAKES THE HEAT

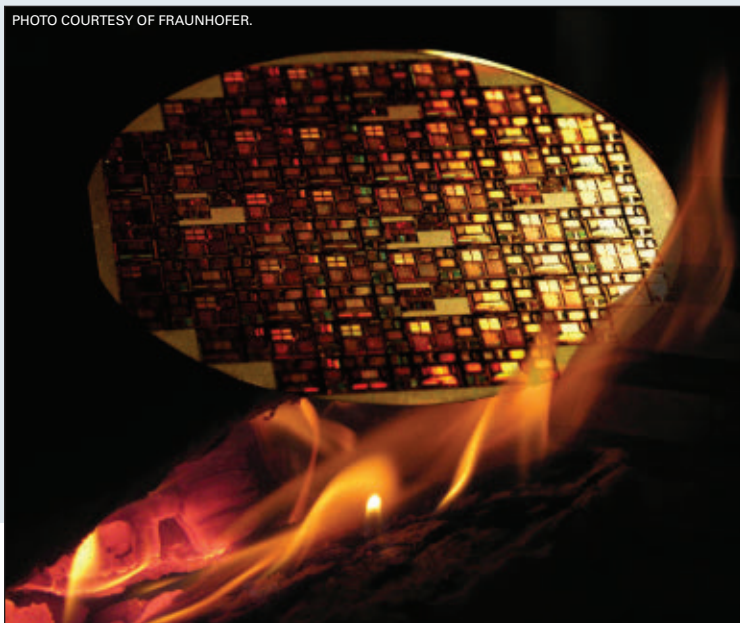
When performing heat-intensive applications such as drilling for oil deposits, you need to employ a range of sensors for things like pressure measurement, porosity evaluation, and so on. The problem is that you run into

some extreme conditions of temperature, pressure, and shock that make life rough for sensor systems. Conventional pressure sensors can withstand temperatures of only about 80 to 125°C (176 to 257°F) which is below ambient temperatures encountered at great depths. But Germany's Fraunhofer Institute for Microelectronic Circuits and Systems has developed a sensor that has been demonstrated to withstand 250°C (482°F) and, in theory, should survive 350°C (662°F), so you could even use it to, oh, test the internal pressure of the Thanksgiving turkey while it's in the oven.

The secret is the use of a silicon oxide wafer instead of monocrystalline silicon which provides better electrical insulation and prevents leakage currents that cause most sensors to fail at high temperatures. Unfortunately, the sensors are still in the R&D phase and not yet commercially available. They have great potential for geothermal and automotive applications, so watch for their appearance after some further studies of performance and endurance have been completed. ▲

■ Silicon oxide wafer used for high-temp pressure sensors.

PHOTO COURTESY OF FRAUNHOFER.



KEYLESS KEYBOARD FINDS MULTIPLE APPS

Back when engineer Pete McAlindon was a grad student showing early signs of carpal tunnel syndrome, he began thinking about how someone might be able to type without actually typing. He started by thinking about a device that combined two eight-position joysticks, providing $8 \times 8 = 64$ positions, plus a shift key to double the number to 128 (which just happens to be the number of characters in the ASCII table). This epiphany led McAlindon to design the orbiTouch keyless keyboard which allows users to input conventional keystrokes by manipulating two grips without the need for painful wrist action. He eventually founded Blue Orb to market the device, and it has proven useful to people with a range of disabilities, including not only CTS patients but people with autism, cerebral palsy, and even — via a Braille overlay — the blind.

The kicker is that the technology behind orbiTouch has morphed into a software application called SwitchBlade Pro for people who are into online gaming on their PCs. Apparently, these folks are often plagued by numb fingers and clumsy movements that a standard keyboard creates. SwitchBlade maps all of the functions of a keyboard and mouse onto a standard game controller

so you can use your Xbox, Playstation 3, Saitek P2900, or Logitech Dual Action unit on the PC. The website (www.switchbladepro.com) appears to offer a free demo download but when I clicked on the button, it took me directly to the "buy" page. Use of the product is by subscription and prices at \$1.99/month or \$19.99 annually. Note that if you pay for a year and get tired of it after a month, you lose: No refunds are offered. Incidentally, if you want the orbiTouch itself, don't try logging onto www.blueorb.com; it will automatically switch you to the SwitchBlade site. You'll need to use www.orbitouch.com and be willing to pay \$399 for it. ▲

■ The orbiTouch keyless keyboard.



INDUSTRY AND THE PROFESSION

PSYSTAR THROWS IN THE TOWEL

If you have been enjoying the David vs. Goliath battle between Apple and "hackintosh" builder Psystar, be advised that the drama could be at an end. Bowing to a court order decreeing them to be "hardcore copyright infringers," they have stopped selling the Open Computer clone boxes, as well as Rebel EFI — a software product that allows the Mac OS X to run on PCs. The dispute is based on Psystar's belief that, "If you purchase an off-the-shelf copy of OS X Snow Leopard, it's your right to use that software" anywhere you want, including on machines not built by Apple. Sounds fair enough. If I don't like my Ford, I have every right to yank out the engine and drop it into a Jeep. But David had no rock in his sling, as the OS X end-user agreement says, "You agree not to install, use or run the Apple Software on any non-Apple-branded computer, or to enable others to do so." You can visit their website (www.psystar.com), though, and buy a \$15 t-shirt that reads, "I sued Psystar ... and all I got was a lousy injunction." You can also make a donation to their defense fund. Yeah, right.

MOBILE DEVICE PROLIFERATION PREDICTION

According to a report from the market intelligence gurus at IDC (www.idc.com), the worldwide number of mobile devices accessing the Internet was 450 million in 2009. Driven by the popularity and declining price of mobile phones, smartphones, and other wireless devices, IDC predicts that the number will surpass one billion by 2013. Over the next four years, IDC expects the fastest growing applications to include making online purchases, participating in online

communities, and creating blogs. Accessing online business applications and corporate email systems will also grow rapidly as businesses move to empower their mobile workforce. China will continue to be the largest user, with 566 million in 2013 (vs. 359 million today), with the USA lagging behind with only 280 million (vs. 261 million now). I suppose this means I'll have to give up my princess phone soon. **NV**

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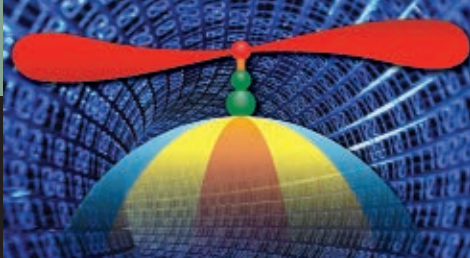
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SPIN_{ZONE}

ADVENTURES IN PROPELLER PROGRAMMING

■ BY JON WILLIAMS

BASIC PROPELLER PROGRAMMING

We knew it had to happen, right? After all, Parallax and BASIC go together like macaroni and cheese. On their own, the elements are great. When you get them together, you create absolute magic!

I think it's safe to say that more than a few Parallax customers were disappointed when the Propeller arrived and couldn't be programmed in BASIC. Like me, many of these customers had invested years learning and working with BASIC, and a good portion of that group had a lot of time with embedded projects thanks to PBASIC. Now, I'm not being critical. Spin is okay with me and I'm quite comfortable with it. That said, I've been programming in one form of BASIC or another for almost 30 years, and that kind-of makes BASIC a little bit hard to give up.

Well ... good news! The team that developed SX/B (headed by Terry "Bean" Hitt) has taken the lessons learned from that product and created a BASIC language compiler for the Propeller: PropBASIC. So, if you've been holding off getting into the Propeller because you couldn't use BASIC, you have no more excuses.

WHAT IS PROPBASIC, ANYWAY?

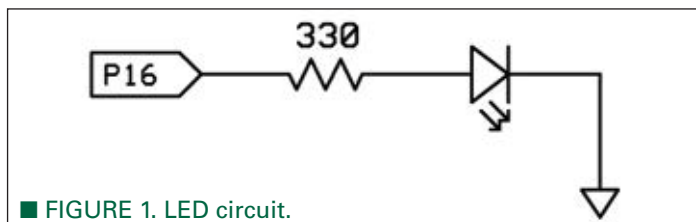
Beyond the obvious, of course, PropBASIC is a single-pass compiler that generates Propeller assembly code so that our programs run at the fastest speed possible. The output is one or more Spin files that can be downloaded to the Propeller. In version 1.0, the main program code is limited to a single cog. Don't let this bother you — Propeller assembly is very powerful and processes that take several assembly instructions in other micros are handled with a single instruction in the Propeller. To top that, we have seven additional cogs available and PropBASIC lets us use them with tasks. In the future, it is very likely that PropBASIC will adopt [Propeller whiz] Bill

Henning's LMM (large memory model) architecture, allowing the compiled output to run from the Hub RAM, breaking the 2K limit imposed by a cog.

For those that have used SX/B, PropBASIC will seem very familiar and you should be able to migrate many of your projects with just a few changes. If you're coming straight from the BASIC Stamp (or one of its many work-alikes), you'll find PropBASIC similar to PBASIC, though not directly compatible. Trust me, it's not a problem; the learning curve is very small. Many of us — myself included — transitioned from the BASIC Stamp to the SX using SX/B. The transition from PBASIC to PropBASIC will be just as easy, and a lot of fun. Yes, you'll have to get used to a slightly new way of doing things, but once you do you'll wish you'd made the transition to a multi-core processor sooner!

HELLO, PROPBASIC

Every PC programming book, no matter the language it teaches, starts out with the now infamous "Hello, World" program. Starting simple is smart as it allows us to get the fundamentals in place before tackling the big stuff. In the microcontroller world, we tend to blink an LED. Trivial? Yes. Important? Yes! If we can't blink an LED, then we certainly can't expect to control a multi-axis robot using GPS input, now can we? Go ahead and connect an LED circuit as shown in **Figure 1**. If you have a Propeller demo board, that LED is in place.



■ FIGURE 1. LED circuit.

Nothing drives me nuttier than messy program listings – I hate them. An easy way to get a neat listing in the end is to start with a clean template. In the downloads file (available at www.nutsvolts.com), you'll find *template.pbas* which is what I use to start most projects (I have a few other templates, based on different project types). Starting with *template.pbas*, I've created *hello.pbas* which we'll work through to introduce the elements of a PropBASIC program. Of course, not all sections of the template are used for a simple LED blinker, but we'll introduce them anyway, and then explore them later.

Again, if you've worked with SX/B, much of this will be very familiar. If you're coming from the BASIC Stamp, there will be some new things to get used to. Trust me, you can, and when you do so many neat things will open up for your [perhaps postponed] projects.

All right, let's go through it, section by section.

DEVICE SETTINGS

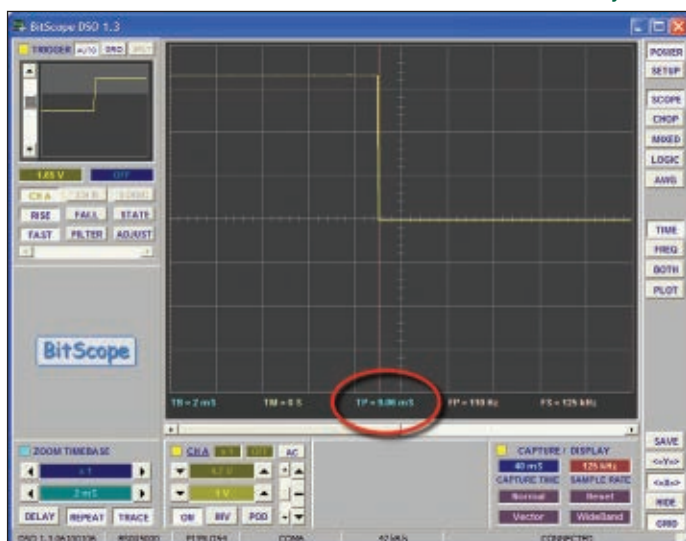
| | |
|--------|-----------------------|
| DEVICE | P8X32A, XTAL1, PLL16X |
| XIN | 5_000_000 |

We'll start nearly every PropBASIC program with this "standard" setup; it declares the Propeller 1 (P8X32A), running with an external crystal, using a PLL multiplier of 16x. The external crystal frequency is 5 MHz which gives us a system frequency of 80 MHz (5 x 16).

There are, of course, options to the standard setup. For low power applications that are not timing-sensitive, we can select one of the RC modes. *RCFAST* runs the chip at about 12 MHz while *RCSLOW* runs the chip at about 20 kHz. To run in *RCFAST* mode, we can reduce the setup to this:

| | |
|--------|--------|
| DEVICE | P8X32A |
|--------|--------|

■ FIGURE 2. *RCSLOW* not adjusted.



When no mode is specified, the compiler assumes *RCFAST*; to use *RCSLOW*, we must specify it in the *DEVICE* directive. In RC modes, the PLL is always 1x and the *XIN* value is ignored. Again, RC modes should only be used in programs that are not timing-sensitive, as the RC oscillator varies from chip to chip. RC modes would not, for example, be good to use when serial communications is a requirement.

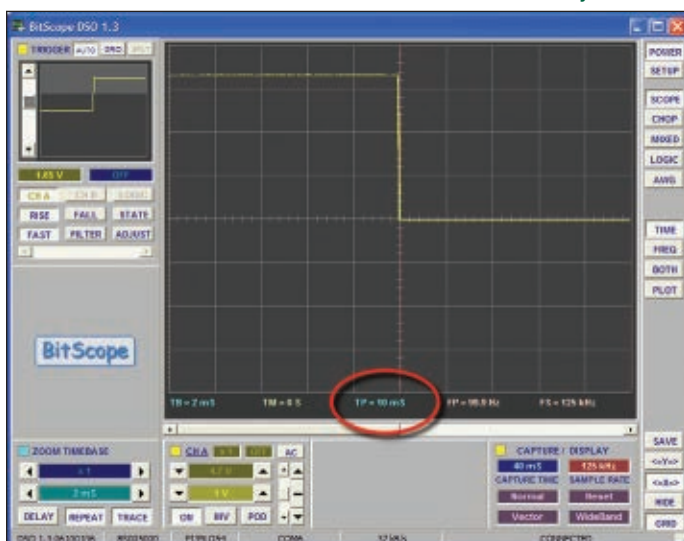
That last statement probably caused you sharp folks to raise a Spock-like eyebrow. If RC modes are no good for serial communications, then how can the IDE reprogram the Propeller when no crystal is attached? Good question. The IDE actually times the Propeller as part of the download protocol and then adjusts the baud rate from the IDE to accommodate the individual chip. So, if you really have to use serial communications and need a low clock speed to reduce current consumption, you can do it but you'll need to do a couple extra steps:

- Measure the clock speed in RC mode (with no *FREQ* specified). You can do this by measuring the width of an output pulse using an oscilloscope.
- Override the assumed RC frequency by using the *FREQ* directive instead of *XIN* (which doesn't apply to RC modes, anyway).

Let's say we create a program (see *speed_test.pbas*) to output a 10 ms pulse and on a 'scope we measure – as I did – a pulse width of 9.06 milliseconds. This means that the processor is actually running a little faster than expected. We can calculate a scale factor for the assumed clock frequency by dividing the measured pulse width into the 10 milliseconds we expected.

$$\text{scale} = 10.0 / \text{measured}$$

■ FIGURE 3. *RCSLOW* after adjustment.





In my case, the scale factor works out to 1.1038. I had selected `RCSLOW` mode which has an assumed frequency of 20 kHz. With the adjustment, the top of my program is now:

| | |
|--------|----------------|
| DEVICE | P8X32A, RCSLOW |
| FREQ | 22_075 |

The `FREQ` setting will drive the compiler and in the end, we'll have corrected timing for things like `PAUSE`, `SEROUT`, etc. **Figure 2** shows the uncorrected output (without using `FREQ`) from my test; **Figure 3** is after the `FREQ` setting has been added.

PROGRAM CONSTANTS

The next section of the template involves defining constants. There's no mystery here with standard numeric and single character constants.

| | | |
|----------|-----|-----|
| OnTime | CON | 250 |
| OffTime | CON | 750 |
| IsOn | CON | 1 |
| IsOff | CON | 0 |
| Asterisk | CON | "*" |

If a program will be using `SERIN` or `SEROUT`, then the baud mode constant is defined like a string.

| | | |
|------|-----|---------|
| Baud | CON | "T9600" |
|------|-----|---------|

This definition can be used to drive `SERIN` and `SEROUT` in true mode (standard when using the programming port) at 9600 baud. Mind you, I'm just using this as an example. PropBASIC compiles to assembly and when running at 80 MHz, we can have very fast baud rates.

Constants are global in a PropBASIC application and can be used in multiple cogs (i.e., the main program and any tasks that run).

I/O PINS

| | | | |
|-----|-----|----|-----|
| LED | PIN | 16 | LOW |
|-----|-----|----|-----|

Declaring I/O pins in PropBASIC is very much like PBASIC 2.5 and SX/B, while using the SX/B convention of allowing the pre-assignment of the pin state immediately after a reset. The options for a pin are `INPUT` (default), `OUTPUT` (same as `LOW`), `LOW`, and `HIGH`. In my programs that will communicate with a terminal program, I include these `PIN` definitions

| | | | |
|----|-----|----|-------|
| RX | PIN | 31 | INPUT |
| TX | PIN | 30 | HIGH |

Note the use of the `HIGH` option; I do this so that auto-generated start-up code places the TX pin in the idle state (output and high) for serial communications through

the Propeller programming port.

PropBASIC allows the definition of a group of I/O pins, as well. For example, there are eight LEDs on the Propeller demo board, connected to P16 through P23. We can define these as a group using the following declaration:

| | | | |
|------|-----|--------|-----|
| LEDs | PIN | 23..16 | LOW |
|------|-----|--------|-----|

In a pin group definition, the first number is the MSB pin of the group, the second is the LSB pin of the group. The order is important as it affects how bits will be presented at outputs or read when the group is set as inputs.

In PropBASIC 1.0, we can only assign a simple value to an output pin group. That means that this line:

| |
|----------------|
| LEDs = %100000 |
|----------------|

is legal, but ...

| |
|----------------------|
| LEDs = 1 << position |
|----------------------|

is not. This is likely to be addressed in a future version. In the meantime, we can use one of PropBASIC's temporary variables like this:

| |
|-------------------------|
| __temp1 = 1 << position |
| LEDs = __temp |

SHARED VARIABLES

PropBASIC allows us to store variables and variable arrays in the Hub that can be accessed by any cog. Hub variables may be defined as bytes, words, or longs, or arrays of either type.

| | | |
|----------|-----|--------------|
| rxHead | HUB | Byte = 0 |
| rxTail | HUB | Byte = 0 |
| rxBuffer | HUB | Byte(64) = 0 |

Note that PropBASIC allows us to pre-assign values to Hub variables. If the pre-assignment option is not used, the variable (and all elements of an array) will be set to zero. Though they are variables, what we store in the Hub cannot be used in expressions like regular variables. There are two instructions — `RDxxxx` and `WRxxxx` — that are used to read and write Hub variables (the instruction used will be based on the variable size; you'll see examples in a moment).

SHARED DATA

Along with variables, we can store shared data in the Hub, as well. With 32K of RAM, this allows for very large tables, and being in the Hub these tables can be accessed from any cog. Hub data can be declared as bytes, words, or longs using, respectively, the `DATA`, `WDATA`,

and `LDATA` directives.

| | | |
|------|------|-------|
| Zip4 | DATA | %0001 |
| | DATA | %0010 |
| | DATA | %0100 |
| | DATA | %1000 |

As with Hub variables, we can access Hub data using the `RDxxxx` and `WRxxxx` instructions. For very large tables/data, we can incorporate external data using the `FILE` directive.

| | | |
|-------|------|------------|
| SFX1 | FILE | "BABY.WAV" |
| SFX1x | DATA | 0 |

DEFINING TASKS

In order for a PropBASIC program to use two or more cogs, we must define `TASKs` to handle the "background" processes. If you've ever programmed the BASIC Stamp, you know how frustrating it is to have to wait around for a serial byte to come in. In SX/B, we could use interrupts to create a background serial buffer, but that could be tedious and many didn't try.

Well, in the Propeller we can simply spawn the physical serial input to another processor using Hub variables to hold everything. The `TASK` definition is simple but needs to be in place before the task can be started.

| | |
|-----------|------|
| SERIAL_RX | TASK |
|-----------|------|

LOCAL (COG) VARIABLES

The variables we use in our program and in tasks are local to the cog and can only be defined as Longs. As with Hub variables, we can also declare arrays and pre-assign values. Here's a typical example:

| | | |
|-----|-----|------|
| idx | VAR | Long |
|-----|-----|------|

PropBASIC creates several local variables for use in the assembly code generated by the compiler, as well as for passing parameters back and forth to subroutines and functions. In the compiled output you'll find five variables — `__temp1` through `__temp5` — that are used in the code generated for PropBASIC keywords. We can use these variables, but with some caution, as they may change if a keyword is used between accesses. I tend to favor using the `__param1` through `__param4` variables when I can. These are only used when passing parameters and do not get modified by the code generated for PropBASIC keywords.

DECLARING SUBROUTINES AND FUNCTIONS

I stated earlier that PropBASIC is a single-pass compiler which means it makes no attempt to optimize

the output code. The good news is that we can learn Propeller assembly tricks by examining the output and minimize code space by using custom subroutines and functions.

In the early days of SX/B (and I'm betting it will happen in PropBASIC, too), some programmers ran themselves out of code space writing seemingly innocuous code. The `PAUSE` instruction, for example, is used in most programs. Let's say we use `PAUSE 100`. The PASM output for that instruction is this:

```

mov    __temp1, cnt
adds   __temp1, _1mSec
mov    __temp2, #100
__L001
waitcnt __temp1, _1mSec
djnz   __temp2, #__L001
```

Okay, it doesn't look like much but if that code is generated for every appearance of `PAUSE`, we can chew through the cog code space pretty quickly. This is easily overcome by encapsulating `PAUSE` in a subroutine. As I did in SX/B, my shell for `PAUSE` is called **DELAY_MS**.

| | | |
|----------|-----|---|
| DELAY_MS | SUB | 1 |
|----------|-----|---|

We only need to pass one parameter because the range of the 32-bit values of the Propeller variables allow for very long delays (two billion plus milliseconds is a *looonng* time).

For those of you coming from SX/B, there is a slight difference in the `FUNC` declaration. In January, after SIRCS project, a Propeller forum member asked for a translation of that functionality to PropBASIC. You may remember that my SIRCS object could return the IR code bits, as well as the bit count. PropBASIC doesn't care how many parameters are coming back from a function (typically just one), only how many parameters are passed to it, hence the definition is:

| | | |
|----------|------|---|
| SIRCS_RX | FUNC | 0 |
|----------|------|---|

THE MAIN PROGRAM

The body of a simple LED blinker program might look something like this:

```

PROGRAM Start

Start:
  FOR idx = 1 TO 3
    LED = IsOn
    DELAY_MS OnTime
    LED = IsOff
    DELAY_MS OffTime
  NEXT
  DELAY_MS 1_000
  GOTO Start
```



Let me explain the `PROGRAM` directive. In addition to indicating the starting point of our code, this directive provides the location for the auto-generated start-up code. In the Propeller, the start-up code is very simple, setting the I/O pin directions and states before jumping to the label indicated in the directive.

As you can see, the code is pure BASIC; every bit as easy to understand as PBASIC, SX/B, or any other variant we've ever dealt with.

FLESHING OUT SUBROUTINES AND FUNCTIONS

At the end of the listing is where we'll place the working code for our subroutines and functions. For the ***DELAY_MS*** subroutine we defined earlier, the code is this simple:

```
SUB DELAY_MS
    PAUSE __param1
ENDSUB
```

As in any other language, one subroutine can call another. In my programs that need to send data to a terminal, you'll find these two subroutines:

```
SUB TX_STR

    strAddr      VAR      __param2
    strChar      VAR      __param3

    strAddr = __param1

    DO
        RDBYTE strAddr, strChar
        IF strChar = 0 THEN EXIT
        TX_BYTE strChar
        INC strAddr
    LOOP
ENDSUB

SUB TX_BYTE
    SEROUT TX, Baud, __param1
ENDSUB
```

The second subroutine is simply a shell for `SEROUT`. The first is used to send a string to the serial port. When calling `TX_STR`, the address of the string is passed in ***__param1*** and captured by the routine. Since we'll need ***__param1*** to send a character to `TX_BYTE`, we use ***__param2*** and ***__param3*** for internal work.

The reason I don't just declare new variables is that everything exists in RAM when using the Propeller, so it's a good habit to minimize variable declarations by using the `__paramx` variables when possible. A new variable that we don't declare frees up space for an assembly instruction.

You probably noticed that the code uses `RDBYTE` to retrieve a character from the string. PropBASIC stores all strings — even those we declare inline — in the Hub RAM to conserve cog space. Of course, we create strings manually using the `DATA` directive:

```
Banner      DATA      "PropBASIC!", 0
```

Function code often looks just like subroutine code except that it is enclosed in a `FUNC`...`ENDFUNC` block and uses `RETURN` just before `ENDFUNC` to send one or more parameters back to the caller. Here's the PropBASIC version of the SIRCS receiver function that I mentioned earlier.

```
FUNC GET_SIRCS

    irCode      VAR      __param1
    irBits      VAR      __param2

    COUNTERA NEG_DETECT, IR, 0, 1
    COUNTERB FREE_RUN, 0, 0, 1

Wait_Start:
    WAITPEQ IR, IR
    PHSA = 0
    WAITPNE IR, IR
    PHSB = 0
    WAITPEQ IR, IR
    IF PHSA < BIT_S THEN Wait_Start

    irCode = 0
    irBits = 0

Check_Frame:
    IF PHSB > MS_044 THEN IR_Done

Wait_Bit:
    IF IR = 1 THEN Check_Frame
    PHSA = 0
    WAITPEQ IR, IR
    irCode = irCode >> 1

Measure_Bit:
    IF PHSA > BIT_1 THEN
        irCode = irCode | $8000_0000
    ENDIF
    INC irBits
    IF irBits = 20 THEN IR_Done
    GOTO Check_Frame

IR_Done:
    __templ = 32 - irBits
    irCode = irCode >> __templ

    RETURN irCode, irBits
ENDFUNC
```


I think you'll agree that this is pretty straightforward, and as it is ultimately compiled to pure assembly code, it runs full speed. So, if you've been wanting to experiment with other IR protocols — perhaps RC-5 — now you have some high-level code to start with (see *sircs_rx.pbas*)

I should point out, too, that PropBASIC includes some Spin and PASM keywords. In the SIRCS example, you can see that I'm using `WAITPEQ` and `WAITPNE` just as in PASM.

FLESHING OUT TASKS

Since a task actually runs in a separate cog, its construction is a little more involved than a subroutine or function. In fact, as a task is its own program, we can — and sometimes must — declare subroutines and functions that run only within the task. All of those declarations and code elements will exist within the `TASK..ENDTASK` block.

Let's create that "background" serial input task that I suggested earlier. What we want to do is have a cog monitor the RX line and when something comes in, write that byte to a circular buffer that can be accessed by another cog. To manage the buffer, we need two variables: a head pointer which is the next open position in the buffer to write; and a tail pointer which is the next position in the buffer to read. When the buffer is empty, the head and tail will be equal.

Here's the code for that task:

```
TASK SERIAL_RX

    rxh          VAR      __param1
    hPntr        VAR      __param2

DO
    SERIN RX, Baud, rxh
    RDBYTE rxHead, hPntr
    WRBYTE rxBuffer(hPntr), rxh
    INC hPntr
    hPntr = hPntr & $3F
    WRBYTE rxHead, hPntr
LOOP

ENDTASK
```

Yep, that's the whole thing. Remember, tasks make use of `CON`, `PIN`, and `HUB` declarations, and we have all of those elements here. At the top of the loop we wait for a byte using `SERIN` — just as we've done in PBASIC and SX/B. The difference here is that the task will be launched into its own cog and waiting for a serial byte in that other cog won't block the main program (unless we let it).

After a byte arrives, we retrieve the current value of the head pointer using `RDBYTE` and then use it as the offset into `rxBuffer` so that we can store the new serial input using `WRBYTE`. The local copy of the head pointer is incremented and ANDed with `$3F` to keep it within the

legal range of the buffer. This value is then written back to the Hub for use by the caller.

There are a couple ways to start a task, though we normally use `COGSTART`.

```
COGSTART SERIAL_RX
```

That's all it takes. We may want to wait a few milliseconds before attempting to access data provided by the task; this allows plenty of time for the other cog to get up and running.

One final note on the `TASK..ENDTASK` block. The PropBASIC compiler will create a Spin file with the name of the task. This means we have to be a little careful with naming tasks so that we don't overwrite regular Spin programs that may live in the same folder.

Okay, so now we have a means of receiving and buffering serial bytes. How do we use them in our main program? What we'll do is create a function that retrieves a byte from the buffer.

```
FUNC RX_BYTE

    rxh          VAR      __param1
    rxt          VAR      __param2
    rxchar       VAR      __param3

DO
    RDBYTE rxHead, rxh
    RDBYTE rxTail, rxt
    LOOP UNTIL rxh <> rxt

    RDBYTE rxBuffer(rxt), rxchar
    INC rxt
    rxt = rxt & $3F
    WRBYTE rxTail, rxt
    RETURN rxchar
ENDFUNC
```

The upper loop retrieves and compares the values of the head and tail pointers; when these values are equal, the buffer is empty. As soon as they differ, we can use the tail pointer as an index into the buffer and grab a byte from it. Just as we did with the head pointer, we update the tail pointer and save it back to the Hub.

Since we took the trouble to write a background serial buffer, let's free ourselves from not being blocked when the buffer is empty. Here's a function that will return the number of bytes waiting in the serial buffer; if zero, the buffer is empty and we can skip calling ***RX_BYTE*** which would cause us to wait for something to arrive.

```
FUNC RX_CHECK

    head         VAR      __param1
    tail         VAR      __param2
    bufcnt       VAR      __param3
```

```

RDBYTE rxHead, head
RDBYTE rxTail, tail
IF head >= tail THEN
    bufcnt = head - tail
ELSE
    bufcnt = tail - head
ENDIF
RETURN bufcnt
ENDFUNC

```

This should be pretty obvious; we're returning the difference between the head and tail buffers. The buffer is

circular and the tail chases the head, so we use `IF...THEN` to prevent returning a negative value when the head pointer has wrapped around past zero and is less than the tail pointer.

ASSEMBLY, ANYONE?

Most of us enjoy compilers because they make writing programs faster and keep us from the nitty-gritty details of assembly. Still, there are times when using assembly is helpful. In PropBASIC, we can include inline assembly using an `ASM...ENDASM` block, or one line at a

time using `\`. PropBASIC generates very nice code so we won't need to use inline assembly often, but it's comforting to know that we can if we choose to do so.

LET'S WRAP IT UP

I can't cover every aspect of PropBASIC in one issue, but I think by now you have an idea of what it is and how to get started with it. As with its SX/B predecessor, PropBASIC includes conditional compilation directives, and the ability to include external assembly and PropBASIC files. It really does have a lot of muscle for a first-generation product — and you can't beat the price (\$0).

THE FUTURE OF PROPBASIC

In a word: exciting. For those of us that use SX/B, we'll tell you that it started out with very humble beginnings and grew into an extremely nice tool. PropBASIC 1.0 is light years ahead of SX/B 1.0 in terms of capability and will just get better. It's natural that the language will expand as we all spend more time with it and offer suggestions to Bean, and the migration to LMM will let us create very large programs, yet still running at the speed of assembly.

So, if you've been waiting for BASIC to play with the Propeller, your wait is over. No more excuses because the compiler is free. Come on, jump on — the ride will be fun. I promise.

Until next time, have fun, and keep spinning and winning with the Propeller and PropBASIC. **NV**

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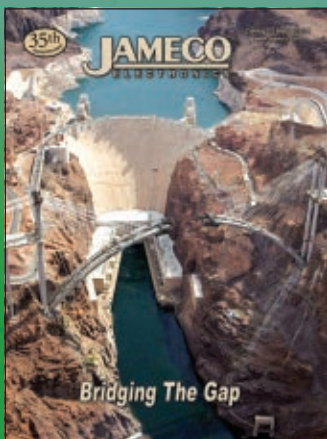
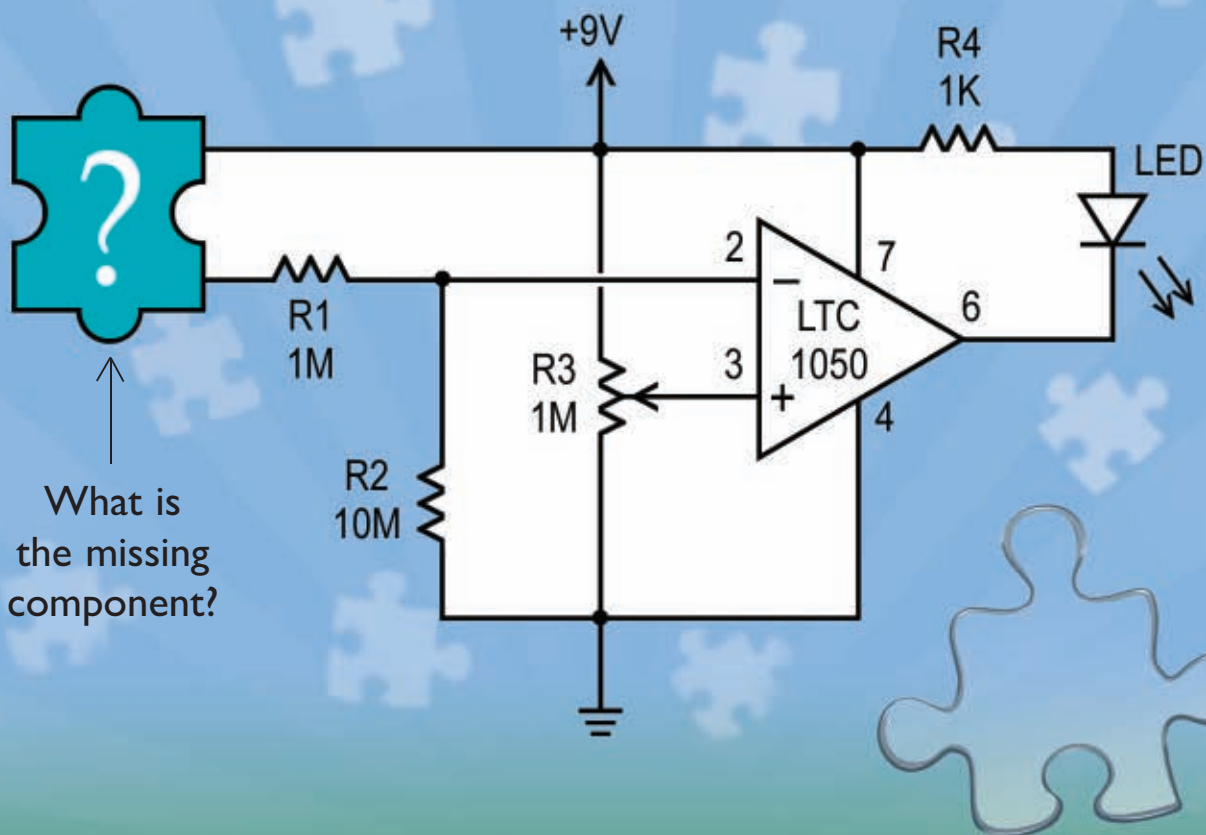
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Both the FM30 and FM35WT operate on 13.8 to 16VDC and include a 15VDC plug-in power supply. The stylish black metal case measures 5.55"W x 6.45"D x 1.5"H. (Note: After assembly of this do-it-yourself hobby kit, the user is responsible for complying with all FCC rules & regulations within the US, or any regulations of their respective governing body. FM35BWT is for export use and can only be shipped to locations outside the continental US or valid APO/FPO addresses or valid customs brokers for end delivery outside the continental US.)

FM30B Digital FM Stereo Transmitter Kit, 0-25mW, Black \$199.95
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MK146 Pocket Vu Meter Kit \$8.95

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This little kit flashes six high intensity LEDs sequentially in order. Just like the K80302 to the right does with incandescent lights. Makes a great mini attention getter for signs, model trains, and even RC cars. Runs on a standard 9V battery.



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This voice changer kit is a riot! Just like the expensive units you hear the DJ's use, it changes your voice with a multitude of effects! You can sound just like a robot, you can even ad vibrato to your voice! 1.5W speaker output plus a line level output! Runs on a standard 9V battery.



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Laser Trip Sensor Alarm

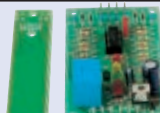
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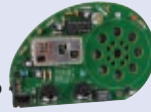
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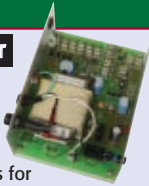
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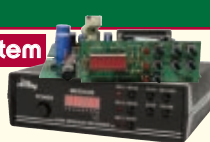


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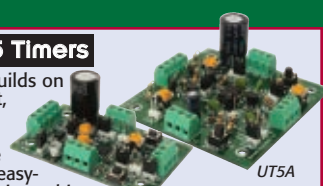
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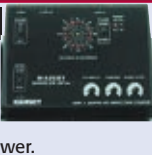
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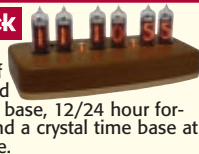
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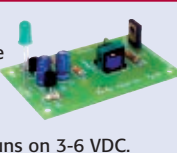
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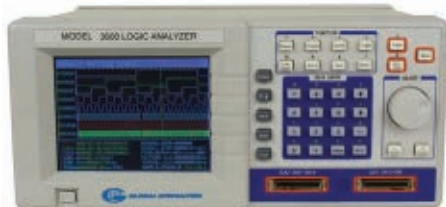
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Q&A

WHAT'S UP:

Join us as we delve into the basics of electronics as applied to every day problems, like:

- ✓ Westminster Chime Sound
- ✓ Soldering Iron Timer
- ✓ IR Transmissive Plastic

■ WITH RUSSELL KINCAID

In this column, I answer questions about all aspects of electronics, including computer hardware, software, circuits, electronic theory, troubleshooting, and anything else of interest to the hobbyist. Feel free to participate with your questions, comments, or suggestions.

Send all questions and comments to:
Q&A@nutsvolts.com

DOORBELL LIGHT

Q First, I always enjoy your response to questions! I would appreciate your suggestion on how to replace a doorbell bulb with a couple of white LEDs. The bulb is connected across the pushbutton and is on until the button is activated. The operating X-former is 15 VAC. Would there be a problem with the inductive kickback from the doorbell solenoid?

— Ray Heller

A The usual doorbell circuit runs on 24 VAC so that is what I assumed in **Figure 1**. The resistor should be a half watt for reliable operation and the inductive kick from the solenoid should not be a problem.

MOTOR SPEED CONTROL

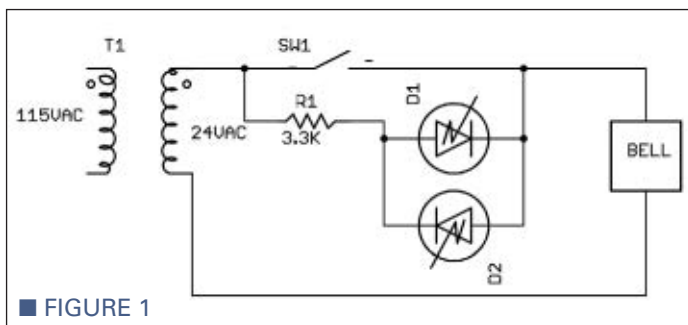
Q I am trying to control the speed of a small band saw motor. The motor specs are: 110 VAC, 3.5 amps, and 1,750 rpm. It is a capacitor start motor running at high speed for wood only. It is built into the housing so it is not practical to use a step pulley to change speeds.

The saw is rigid enough to use on steel with the proper blade if it is slowed down.

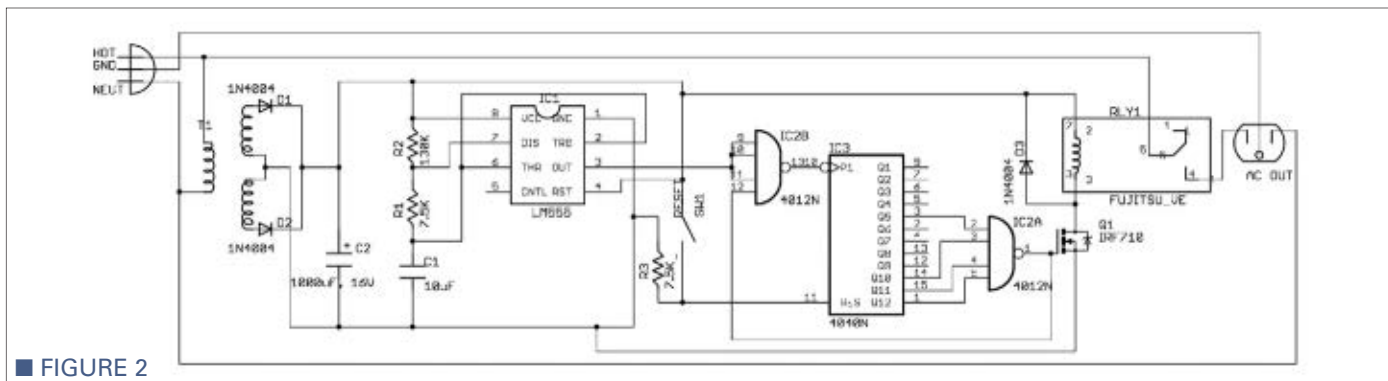
— Charles Forman

A These small AC motors are designed to run in sync with the applied power. In order to change the speed, you have to change the drive frequency. That is not easy to do. Some high-end washing machines have a three-phase motor and controller; it can change direction and speed under the control of a microprocessor. I have one; it appears to be like a stepper motor but I have not figured out how it works.

I believe your motor could be controlled by a microprocessor. The method would be to rectify the input to DC and apply power using MOSFETs at the desired frequency. The capacitor would not be needed. The micro could provide the phase shifted signal to start or reverse the



■ FIGURE 1



■ FIGURE 2

motor. An SCR or TRIAC could not be used because they don't turn off in a DC circuit. Unfortunately, I can't undertake a project like this in this forum; it is just too big a job.

SOLDERING IRON TIMER

Q I am looking for a cheap timer that will last for one hour, then power-off my soldering iron. I have a bad habit of leaving it on. I am guessing that a 555 would do the trick.

— Toby Norton

A One hour is too long for a single 555, so a count down circuit is needed; see **Figure 2**. IC1 is part of a one second astable; IC2 decodes the 12-bit counter to 3,600 counts and turns Q1 off at the end of one hour. To operate, you plug the control box into an outlet; plug the soldering iron into the control box outlet, push the reset button, and the iron will be powered for one hour. To calculate the decoding, subtract the largest binary number from the desired count that will leave a positive result. The binary bits are weighted: 1, 2, 4, 8, 16, ... 1024, 2048, 4096, etc. This is the subtraction:

```

3600
-2048
-----
1552
-1024
-----
528
-512
-----
16
-16
-----
0

```

You will need the Q12 output, plus the 11th and 10th, plus the 2nd output (Q5). The output of IC2A is high until all four inputs are high, then IC2A output goes low, turning off Q1 and stopping the clock. You might think that since 2048 = 2¹¹, then you would want to start with

SOLDERING IRON TIMER PARTS LIST

■ **FIGURE 3**

| PART | DESCRIPTION | MOUSER PART # | COST |
|------------|------------------------|----------------------|---------|
| T1 | 18 VAC CT 1A | 41FJ010 | 8.28 |
| D1, D2, D3 | RECTIFIER, 100V, 1A | 512-1N4004 | 0.07 |
| C1 | 10 μ F, 16V, 10% | 81-GRM31CR61C106KA88 | 0.41 |
| C2 | 1000 μ F, 10%, 16V | 140-HTRL16V1000-RC | 0.25 |
| R1, R3 | 7.5K, 1/8W, 5% | 291-7.5K-RC | 0.40/10 |
| R2 | 130K, 1/8W, 5% | 291-130K-RC | 0.40/10 |
| IC1 | 555 TIMER | 511-TS555IN | 0.72 |
| IC2 | DUAL FOUR INPUT NAND | 595-CD4012BE | 0.40 |
| IC3 | 12-BIT BINARY COUNTER | 595-CD4040BEE4 | 0.43 |
| RLY1 | 12V RELAY, 5A CONTACTS | 817-VE-12H-K | 2.15 |
| SW1 | MOMENTARY PUSHBUTTON | 612-PS1057A-RED | 1.62 |
| Q1 | 100V, 2A MOSFET | 844-IRF710PBF | 0.47 |

Q11. But Q11 goes high at 1024 and goes low at 2048. Q12 goes high at 2048 and stays high until 4096, or until the clock is stopped by the decoded outputs being high. I did not use the 555 reset because that makes the 555 output low (which would be another clock pulse and the count would continue). **Figure 3** is the Parts List.

WESTMINSTER CHIME SOUND

Q I am an avid *Nuts & Volts* reader who has been burning fingers on soldering irons since the early '60s. I was interested to see you using more and more microcontroller solutions and I have started experimenting with PICs myself (I am a software developer by day so the programming part is second nature).

I am hoping you can help me out. I have a PIC-based clock which plays the Westminster chime tune on the hour. The problem is that the "chime" notes are just constant amplitude square waves and I would like to make them sound more like real chimes. I have very little program space left but I do have a couple of unused I/O pins. I was hoping you could come up with something that would modulate the square wave amplitude with an envelope like a real chime. If need be, I can provide a trigger pulse at the beginning of each note.

— Keith Ujvary

A I have a clock that does the Westminster chime and "bongs" on the hour. I connected my scope to the speaker; one of the waveforms is **Figure 4**. Note that the sloping top of the wave varies in amplitude; the waveform is quite complex and I don't think that just reducing the amplitude of the square wave will sound good. I am not going to take my clock apart to see how it is done, but the patent explains it quite well; see www.patenstorm.us/patents/pdf/patent_id/4172359.html. There are other patents that may be of interest: 4358838 and 4271495, and others.

Good luck with your project.

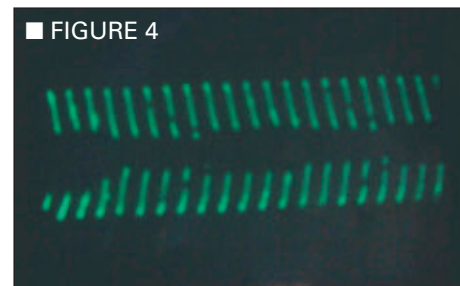
IR TRANSMISSIVE PLASTIC

Q What type of plastic can pass the infrared ray for motion detectors?

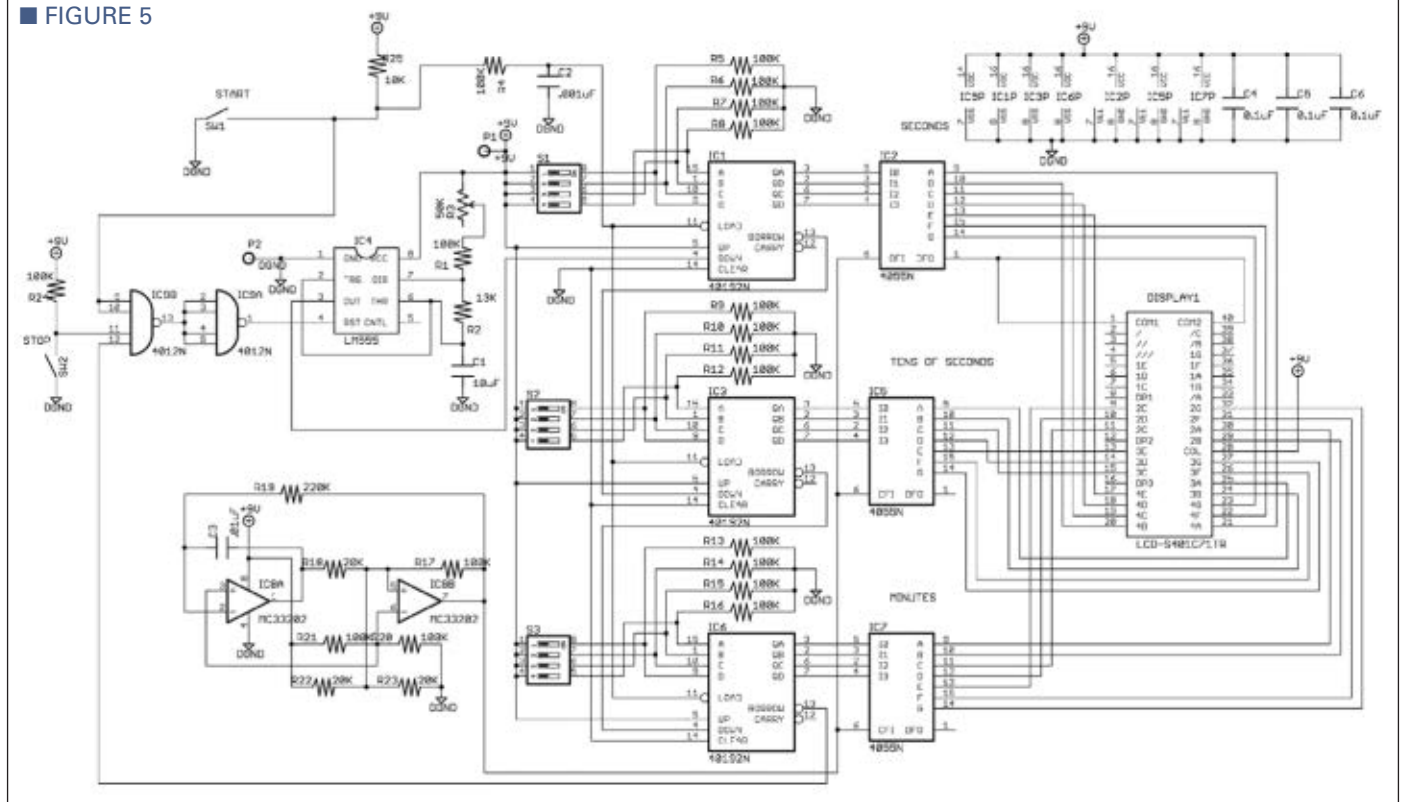
— Sam Botros

A Acrylic plastic is most often touted as IR transmissive (Plexiglas). It is available in black, but you have to

■ **FIGURE 4**



■ FIGURE 5



specify IR transmissive because some black Plexiglas is not. Check out this URL: www.eplastics.com/Plastic/Plexiglass_Acrylic_Sheet_Infrared_Transmitting.

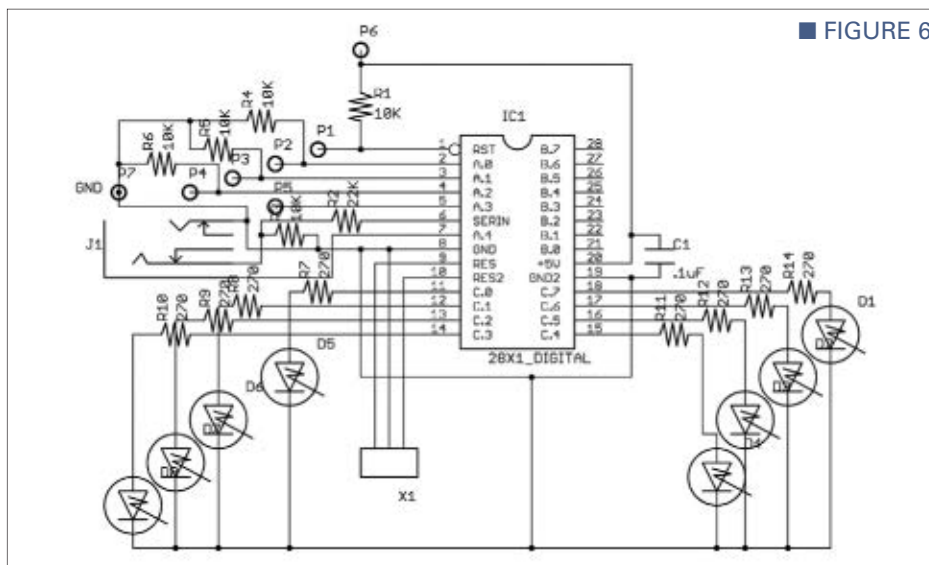
COUNTDOWN TIMER REVISITED

Last month, I presented a countdown timer for Robert Cuneo.

There are some corrections to be made; see the schematic in **Figure 5**. The first problem was I didn't read the datasheet carefully and assumed that digit #1 was seconds and digit 3 was minutes ... wrong! I had it backwards so had to re-do the schematic. Next, I realized that I had not followed the schematic layout and had put the seconds digi-switch in the middle, tens of seconds at the bottom, and minutes

at the top. I wish I had not done that but I was thinking ease of layout instead of ease of use, and consequently did not accomplish either. That was not something that had to be corrected, so I continued. The intention was to have #1 of the digi-switch be the least significant bit (LSB) but I got it backwards so #4 is the LSB. I could have turned the switch around on the schematic but it would have scrambled the layout, so it is much easier to tell you to put the switch in

■ FIGURE 6



MAILBAG

Dear Russell:

In regards to my question in *Nuts & Volts* December '09, page 25. Can I use a toroidal core for the 1.19 mH and the 1.33 mH? If so, how many turns and what core do I use?

— Kendrick Sellen

Response: RadioShack RF choke core #273-104 is readily available and suitable. The AI is 175 mH per 1,000 turns. For 1.19 mH, use 82.5 turns; for 1.33 mH, use 87.2 turns.

backwards if it makes a difference to you! More problems: When the start switch was pressed, the set time was loaded but when the start switch was released, the time immediately went to the next second and started counting from there. I realized then that the clock was low when stopped, so when the load input went high, the counter saw a clock pulse. The solution was to add R25 and move C2 so there is a 100 microsecond delay of the load release which allows the clock to go high first. This illustrates the utility of building a breadboard.

The schematic, layouts, and Gerber files are posted on the *Nuts & Volts* website (www.nutsvolts.com) for those who want to try building this countdown timer. You don't have to mirror the top layer; I have already done that.

LARGE CLOCK REVISITED

Last month, I presented a program for Eric Fulton's large clock. I was not able to program the Picaxe chip and test it so I contacted my eldest son, Wayne, who figured out how to load the drivers so I could program the 28X1 chip. After correcting the errors in the countdown timer, I took a look at the clock test circuit (see the schematic; **Figure 6**). Nothing was happening, so I poked around with the scope; everything was normal except pins 9 and 10 (RES and RES2) were low. It can't work that way; it must be a defective chip or resonator, so I plugged in a new 28X1 (unprogrammed) to check for oscillation ... nothing. Next, I tried a 4 MHz crystal in place of the resonator ... still nothing. I thought maybe it needs to be reset. Ahha! The oscillator works as long as the reset is low but stops when the reset is high. It can't work that way, so if anyone figures out what is wrong, please let me know. Use my email: russlk@yahoo.com and put Large Clock in the subject so I can find it in the spam folder. **NV**



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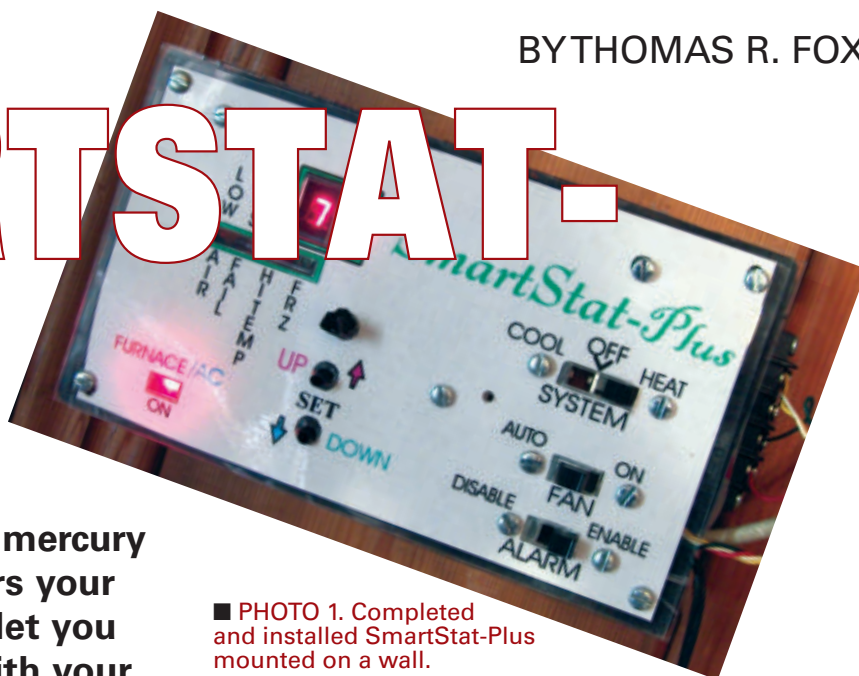
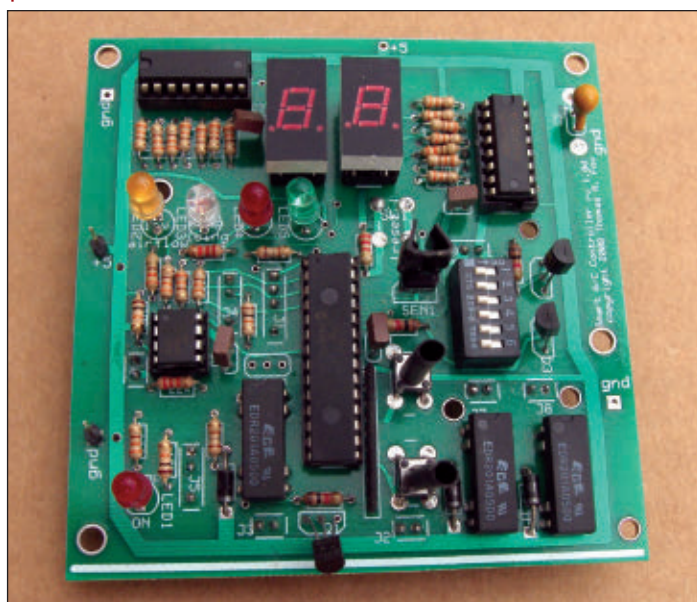
BY THOMAS R. FOX

This MCU-controlled Digital Thermostat not only replaces mercury thermostats but also monitors your furnace/AC air filter and will let you know if there is a problem with your heating/cooling system.

Did you ever wonder what would happen if your furnace's blower motor failed, belt broke, or something completely blocked your furnace's air filter? Well, most furnaces would get hotter and hotter, and the thermostat won't know it until it's too late. If it wasn't for the furnace's built-in high temperature limit control, the furnace would keep going and going and not only destroy itself, but perhaps a fire. If this adjustable safety control happens to be set too high (or is faulty), damage can occur to your furnace before the safety control shuts it off.

A similar thing can happen to a central air system.

■ **PHOTO 2. SmartStat-Plus' completed main printed circuit board.**



■ **PHOTO 1. Completed and installed SmartStat-Plus mounted on a wall.**

Here, the worst scenario is perhaps a fried compressor motor.

(Note: A few systems also use a mechanical "Sail Switch" which is supposed to help solve this and other low air flow problems. However, they are used mainly with electric furnace systems and aren't suited for use in established heating/cooling systems.)

The SmartStat-Plus presented here doesn't just control the temperature, it continually monitors the air flow. This air flow information can be used to determine the relative dirtiness of the filter and is used by SmartStat-Plus to determine if there is a problem with the blower or filter. An option switch on the SmartStat-Plus will give it permission to shut off the furnace and/or A/C if the air flow gets too low. Other safety features include a system failure alert, a dangerously high room temperature alert, and a freeze alert/control.

Other than the filter monitor/alert system and the abundant safety features, the SmartStat-Plus differs from commercially available digital thermostats because it is custom programmable!

What does the wind chill factor have to do with SmartStat-Plus' air flow sensor circuit?

Simply stated, they both depend upon the same heat transfer phenomenon. The explanation goes something like this: If an object is internally heated, the air is warmed next to it. If air movement displaces this air warmed by the object, the object will cool to near the air temperature. Once this warmed air is blown away, stronger air movements have no further chilling effect. This is why winds over 70 mph do not feel colder than 50 mph winds.

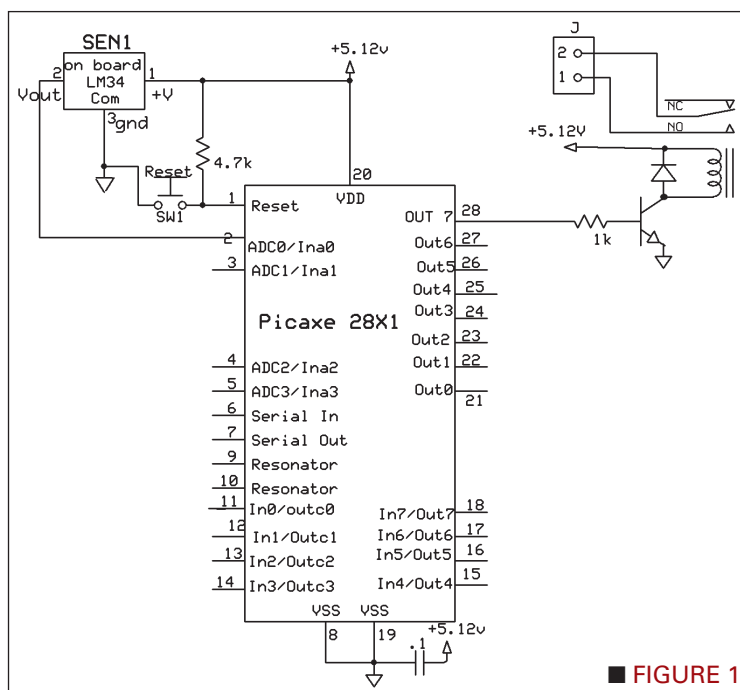
SmartStat-Plus' air flow sensor board uses two LM34

temperature sensors: one LM34 is heated with a 1/4W, 100 ohm resistor that has 50 mA flowing through it and the other LM34 is unheated. When both are subject to a strong air flow, the temperature difference between the two is only a degree or two. However, when the air is calm, the temperature can exceed 20 degrees. Since the LM34 has a voltage output of 10 mV per degree Fahrenheit, the voltage difference between the two ranges from about 20 mV when there is good air flow, to greater than 200 mV with no air movement.

Of course, now that we know how to sense the air flow through the forced air heating/cooling system, we have to design a smart gizmo that can make sense out of the info and do what is necessary. An MCU-based gadget is a natural fit here. While there are many, many MCUs that would work here (I have designed with five other types in the past), I looked into using a PICAXE because I really enjoy designing with it. (It's just plain fun to play ... I mean work with.) For some reason, the words PICAXE and Heathkit make me feel warm and cozy!

We'll need an MCU with at least three A/D converters with a minimum eight-bit resolution. (The PICAXE 28X1 has four A/Ds with 10-bit conversion capability.) In order to have the PICAXE handle the inputs/outputs directly (which simplifies circuitry and firmware), we also are looking at a minimum of five outputs (assuming use of the inexpensive combination of the 74HC595/eight-bit shift registers/output latches and seven-segment LED display) and at least three digital inputs (more are needed to set options). The PICAXE 28X1 comes with more input and output pins than are needed. Because of this abundance of easy-to-use pins, I added several safety features (e.g., alerts for system failure, high temperature, freeze, and several options such as Celsius degrees and an adjustable hysteresis).

To show how easy it is to use the PICAXE 28X1 in a thermostat using an LM34 as a sensor, let's look at a super simple thermostat. The circuit for this thermostat is shown in **Figure 1** and the code is given in **Listing 1**. Notice there is no way to set this simple thermostat — it is preset for 72°F. While this circuit and code should be able to control a furnace to keep a house at 72°F, it is basically too simple and could possibly even damage a furnace because it could turn on and off the furnace too frequently (i.e., high cycle rate). With all that said, this circuit and code forms the heart and soul of the SmartStat-Plus so we will look at it to get the basics of SmartStat's operation, along with the PICAXE's Basic software. (You can download the source code for



■ **FIGURE 1**

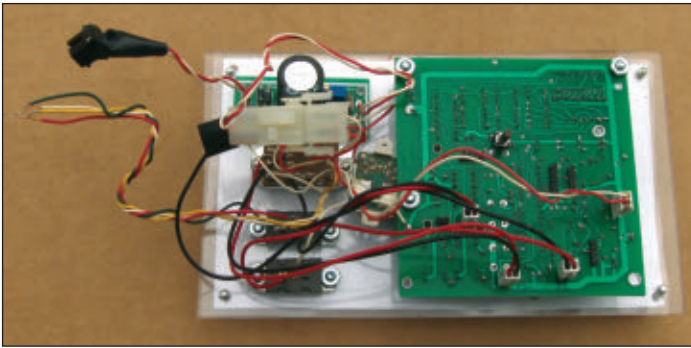
SmartStat-Plus itself from the N&V website at (www.nutsvolts.com/index.php?/magazine/downloads/) and also from www.magiclandelectronics.com.)

Referring to both **Figure 1** and **Listing 1**, notice a relay circuit is connected to the 28X1 chip pin 28 which is Out 7; the output of the temperature sensor LM34 will be connected to chip pin 2. Chip pin 2 is the ADC0 input (Analog-to-Digital Converter). Since the power supply is set at exactly 5.12 volts, the 10-bit A/D converter measures voltage in steps of 5 mV (5.12/1024). Also, the LM34 produces an output of 5 mV per 1/2 deg F (10 mv/deg F). This means every step of the A/D's output corresponds to 1/2 deg F (5/18 deg C).

Notice the first line of code "Symbol Furnace=7". The purpose of this line (like all the lines that use the Symbol

LISTING 1

```
*****
Listing 1
'This simple thermostat program will turn on the furnace if
'the temperature drops below 72
'it is assumed the power supply is set at 5.12 volts
Symbol Furnace=7      'Renames Output 7 to "Furnace"
Symbol Temperature=b1  'Renames variable b1 to "Temperature"
Symbol SetTemp=b2     'Renames variable b2 to "SetTemp"
SetTemp=72            'It is assumed the thermostat will be set at 72
do
  'main loop
  readadc10 0, Temperature      'take 10-bit temperature data
  Temperature=2*Temperature     'modify data for iwhole deg F
  if Temperature<SetTemp then   'if room temp drops below 72
    high Furnace                'turn on furnace
  else
    low Furnace                 'make sure furnace is off
  endif
  pause 1000 'pause here to help slow things up a bit
loop
*****
```



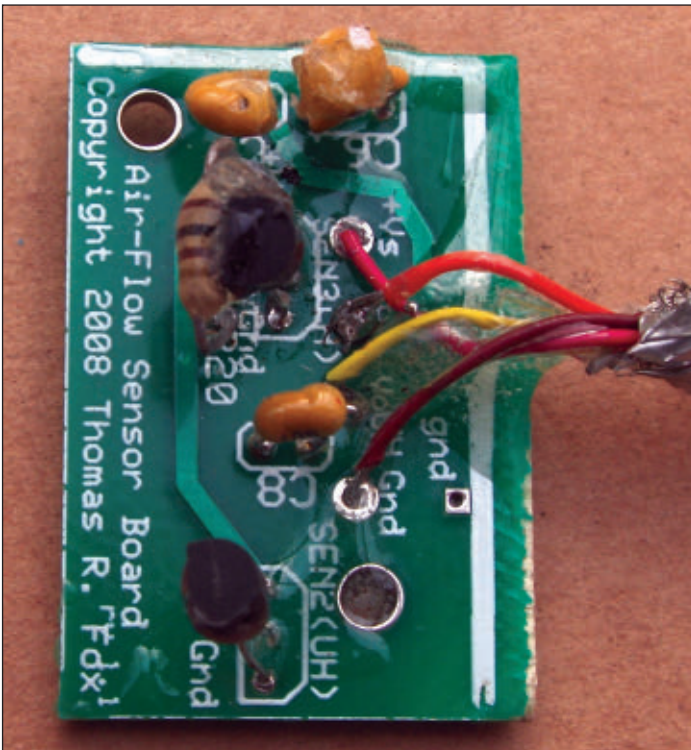
■ **PHOTO 3.** The inside wiring of SmartStat-Plus including PCB and switches.

command) is to make the code more programmer-friendly. Here we set the word "Furnace" equal to 7; from then on, Furnace will be interpreted as 7. So, when the PICAXE encounters the statement *high Furnace* it will switch its Out 7 pin ON which will turn on the furnace. (Remember, the Out 7 pin is connected to the PICAXE's chip pin 28; see **Figure 1**.)

The next line of code "Symbol Temperature=b1" does basically the same thing. It sets Temperature equal to b1. Here, b1 is an eight-bit storage location in the PICAXE which is normally referred to as a "byte variable." The next line "SetTemp=b2" does the same except it renames the byte variable b2 to "SetTemp." The "SetTemp=72" command line stores 72 at the PICAXE storage location b2. This is the temperature we have preset into the program.

Next, the program goes into the main Do loop. The

■ **PHOTO 4.** Close-up of completed air flow board.



"readadc10 0, Temperature" command line tells the PICAXE to use its 10-bit A/D converter on the voltage at its ADC0 input (chip pin 2) and to put its 10-bit result at storage location Temperature (byte variable b1). The next line simply multiplies the result by 2 since (in the previous line) we were dealing with data of half degrees.

The next four lines provide the smarts (though very, very limited) for the thermostat. The if...then...else statements simply turn on the furnace if Temperature is less than SetTemp (which is 72). It will then turn the furnace off (or make sure it is off) if the temperature gets above 72. This provides a small ($\pm 1^\circ\text{F}$) hysteresis. The pause 1000 statement creates a one second delay in an attempt to slow things down, although this is not enough for a practical thermostat. The "loop" statement provides continuous looping here.

One obvious problem is that we assume everything is perfect and so we only take one temperature reading. In the SmartStat-Plus, we take 630 readings and then take their average.

The subroutine from the SmartStat's source code that does this is:

```
'Code used to read temperature 630 times and
take average
'also converts to celsius
ReadTemperature:
    SumTemp = 0
    Temp = 0

    for K = 1 to 63
        readadc10 0, Temp
        SumTemp = SumTemp+Temp
    next K
    CurTemp = SumTemp/63/2 MIN 0

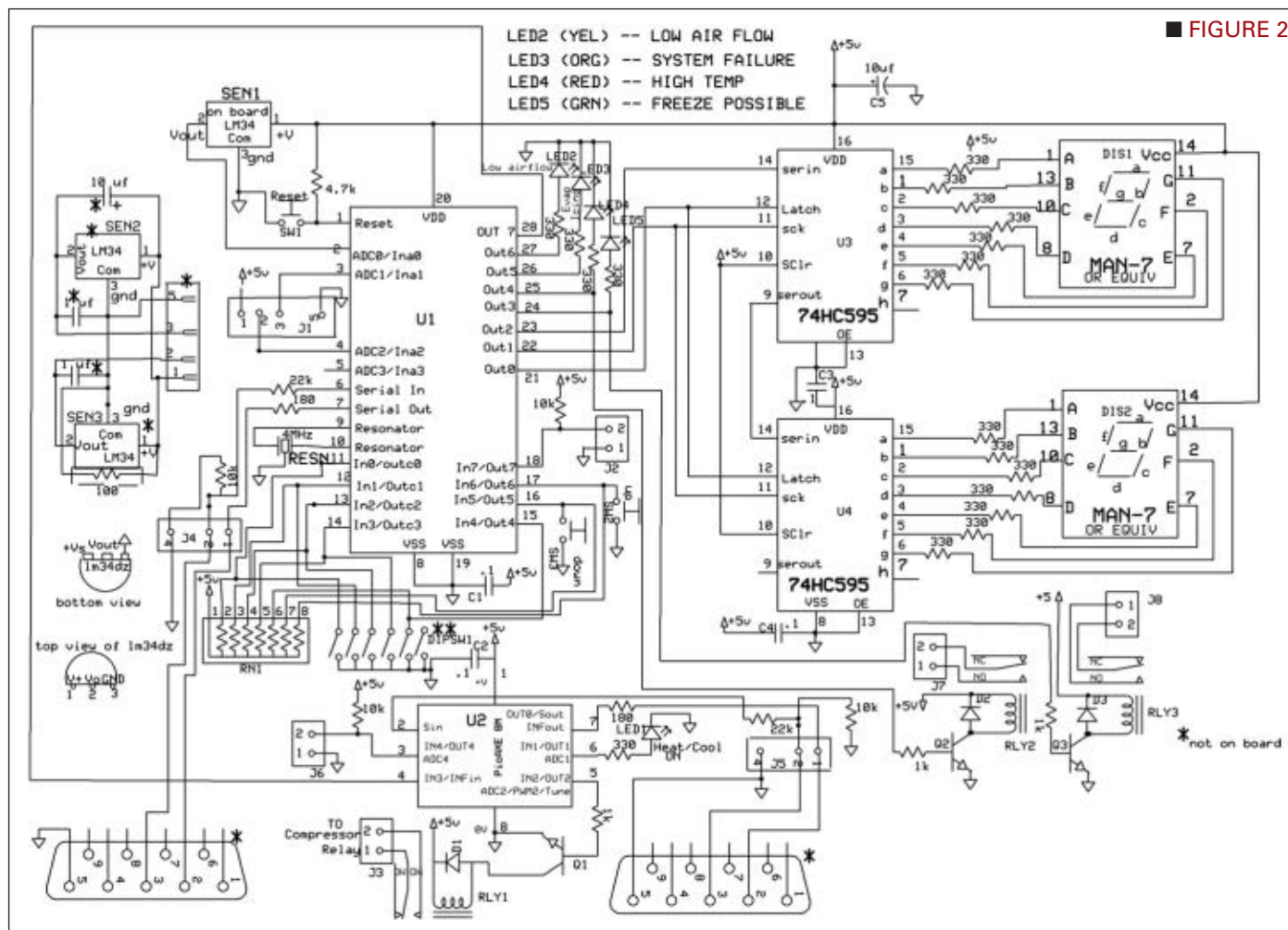
    for L = 1 to 9
        SumTemp = 0
        Temp = 0
        for K = 1 to 63
            readadc10 0, Temp
            SumTemp = SumTemp+Temp
        next K
        Temp = SumTemp/63/2
        CurTemp = Temp + CurTemp/2 MIN 0
    next L

    if CelsiusFlag = 1 then
        CurTemp = CurTemp - 32 * 5 / 9
    MIN 0
    end if
    return
```

Notice this subroutine also calculates the Celsius temperature.

Notice from the SmartStat-Plus's schematic in **Figure 2** that the 28X1 doesn't directly control the relay that

■ FIGURE 2



controls the furnace or A/C. It merely lets another MCU (a PICAXE 08M) know that it “thinks” the furnace or A/C should go on. The 08M takes over from there and starts a delay routine (40 seconds for heat and five minutes for cool). Only after this delay is over will it actually switch on the control relay. While this delay can be designed into the 28X1 source code, I felt it was important enough to have a separate MCU handle the job. The source code for the 08M is also available for those interested in changing the default settings.

Building It

While the early designs of this project were tested on a solderless breadboard, it is recommended that it be constructed using a printed circuit board (PCB). For those who want to make their own main board, the patterns for it and the air flow sensor are available in the download package.

Pay close attention to the **Figure 2** schematic while wiring the SmartStat-Plus.

For easier access, mount J1 through J8, SW1, and DIPSW1 on the foil side. For increased accuracy, use a small heatsink for SEN1 and make sure at least part of the

heatsink is outside the case (if not the whole thing).

Here’s a tip: SW2 and SW3 are tactile PC switches. Assuming you are going to mount the PCB to the back of a panel, you will need to drill holes in the panel *and* add to the length of the buttons. I used a 3/4” long 1/8” diameter piece of heat-shrinkable tubing.

Powering It

Since the air flow sensor uses about a quarter of a watt to function, it isn’t practical to power it with a battery. I used a small 9 VAC wall-wart that powers an adjustable 5V power supply. (See its schematic in **Figure 5**.) I then adjusted the power supply’s output for exactly 5.12V for optimum accuracy since the firmware assumes a 5.12V reference voltage.

Programming the Two PICAXEs

The programming port for the 28X1 is J4 and the port for the 08M is J5. If your computer has an RS-232 serial interface, connect pin 1 of J4 or J5 to pin 2 of a nine-way D female socket; pin 2 of J4 or J5 to pin 3 of the nine-way D female socket; and pin 4 of J4 or J5 (the ground pin) to

temperature, the FURNACE/A/C ON LED should start to flash which indicates it is about to turn the furnace on. When this LED lights steadily, the furnace will be signaled to turn on.

Now, put the SYSTEM switch to the OFF position, connect the air flow sensor board, and turn to HEAT again. The display should show the temperature. Wait six minutes and then press both UP/DOWN switches simultaneously. The display should show AF (Air Flow) and then a number — this number is the relative air flow level. Since there is no air flow, the number should be below 50. Now, use a fan to blow at the sensor. The number displayed should rise to over 80. Press either the UP/DOWN button and the display should flash the pre-set critical air flow level. This critical level can be changed using the UP/DOWN buttons. After 10 seconds, the display will again show the temperature. If everything looks okay, then it's time to install the SmartStat-Plus.

Installation

If you are replacing a heating/cooling thermostat, you should have enough information from **Figure 6** to install it in most systems. Notice the little 24 VAC transformer in the schematic is part of your heating/cooling system.

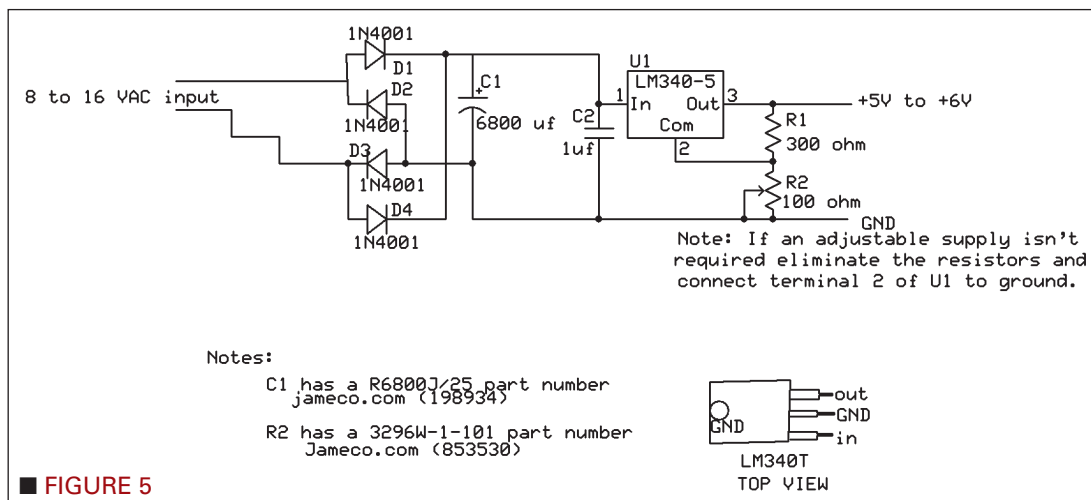
Note: Some heat only systems do not have an external fan lead. In this case, leave G unconnected and eliminate the Fan switch.

Since SmartStat-Plus has the additional feature of an air flow monitoring/alert system, you will also need to place the air flow sensor board in an appropriate location. A convenient location is in a heating/cooling vent close to the thermostat. However, if you wish to monitor the dirt in the air filter, it is best to place it near the air filter itself.

If you don't have whole house A/C or you only have whole house A/C (no furnace), you can leave out switch SW4. SW5 and SW6 are also optional, as is A1.

Final Thoughts

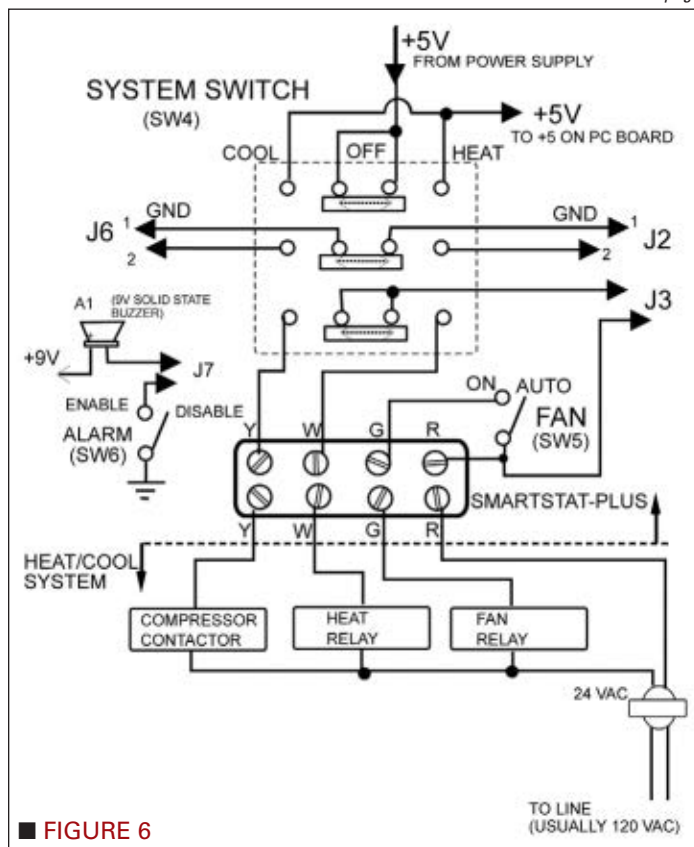
The source codes are supplied and there are connectors on the board which allow the software to be



■ **FIGURE 5**

reprogrammed at any time so users can easily modify the SmartStat-Plus. For instance, some things that can be changed are the compressor off-time, heater off-time, CPH, hysteresis, DIP switch options, default settings, and more. The source code was purposely written so users don't need to know the exact workings of the code in order to modify the SmartStat-Plus. Now you can keep your cool (and warm!) without worrying. **NV**

Parts List on next page



PARTS LIST

| QTY | ITEM | DESCRIPTION | PART NUMBER |
|-----------------------|------------|---|-------------------------------------|
| Semiconductors | | | |
| 3 | D1-D3 | 1N4001 silicon rectifiers | 1N4001 |
| 3 | Q1-Q3 | NPN transistor TO-92 | PN2222A |
| 3 | SEN1-SEN3 | LM34 temperature sensor | LM34DZ |
| 1 | U1 | 28X1 PICAXE | PICAXE-28X1 |
| 1 | U2 | 08M PICAXE | PICAXE-08M |
| 2 | U3, U4 | 74HC595 eight-bit shift reg/out latch | 74HC595N |
| LEDs | | | |
| 2 | DIS1 | .3" seven-segment common anode LED display | UA3051-12 (Jameco.com 334984) |
| 1 | LED5 | Green T1-3/4 LED | LTL-307G (Jameco 697531) |
| 1 | LED2 | Yellow T1-3/4 LED | LHY3330/HO (Jameco 333622) |
| 1 | LED3 | Orange T1-3/4 LED | BVT-5E1QT4ER (Jameco 197683) |
| 2 | LED1, LED4 | Red T1-3/4 LED | UT1871-81-M1 (Jameco 333973) |
| Resistors | | | |
| 19 | R1-R19 | 1/4W, 330 OHM | |
| 1 | R20 | 1/4W, 100 OHM | |
| 1 | R21 | 1/4W, 4.7K | |
| 2 | R22, R23 | 1/4W, 22K | |
| 2 | R24, R25 | 1/4W, 180 OHM | |
| 4 | R26-R29 | 1/4W, 10K | |
| 3 | R30-R32 | 1/4W, 1K | |
| 1 | RN1 | Ten-pin 10K in-line resistor network | 4310R-101-103 (Jameco 857160) |
| Capacitors | | | |
| 4 | C1-C4 | 1 mfd 50V capacitor | |
| 1 | C5, C6 | 10 mfd 25V axial electrolytic capacitor | |
| 1 | C7, C8 | 1 mfd 50V capacitor | |
| Hardware | | | |
| 1 | J1 | 5 pin .100" male header (remove pin 4) | 22-23-2051 (Jameco 232291) |
| 4 | J2, J6-J8 | 2 pin .100" male header | 22-28-4020 (Jameco 879406) |
| 2 | J4, J5 | 4 pin .100" male header (remove pin 3) | 22-23-2041 (Jameco 232282) |
| 3 | SW1-SW3 | Tactile switch with 17"x.25" lead spacing | KT11P4CM (Jameco 149948) |
| 1 | SW4 | Three pole three position slide switch (eyelet terminals) | 3P3T switch (Digi-Key.com SW336-ND) |
| 2 | SW5, SW6 | SPST slide switch (eyelet terminals) | SPST switch (Digi-Key SW148-ND) |
| 1 | DIPSW1 | Six position DIP switch | 76SB06ST (Jameco 696909) |
| Miscellaneous | | | |
| 1 | A1 | 6-12V piezo buzzer | MSR320 (Jameco 335557) |
| 3 | RLY1-RLY3 | 5V DIP relay | 201A05 (Jameco 106463) |

Other

Power Supply, terminal strip, connectors, wire, case, etc.

Note: PICAXEs are available from www.sparkfun.com and www.phanderson.com

Printed Circuit Boards— PCBs for the MCU, the air flow sensor, and the adjustable 5V power supply and sensors board are available from Magicland Electronics (www.magiclandelectronics.com).

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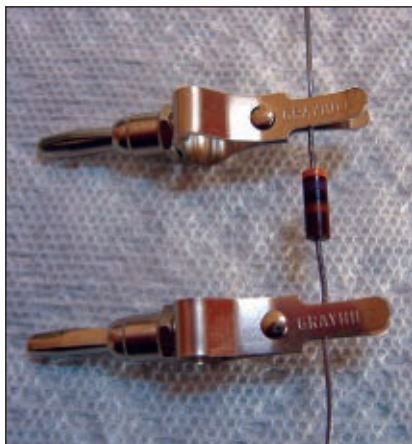
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BUILD YOUR OWN ELECTRONICS TEST FIXTURES

Like many readers of *Nuts & Volts*, you probably have a need for test fixtures. Test fixtures allow you to rapidly test capacitors, resistors, diodes, transistors, etc. Test fixtures also provide a stable environment to replicate conditions for testing so that devices of a certain type can be compared. If you are troubleshooting circuits that are already constructed, a test fixture is probably unnecessary, although an assembly can test components under actual circuit conditions. There's also the possibility you might need to remove components for testing out of the circuit.

While assembling electronics chassis, manufacturers can build fixtures for testing multiple assemblies. It is unlikely the hobby builder will require this. Without test fixtures, discrete components that are difficult to hold while measuring their parameters create undesirable variables and conditions. If you need to test components that require high voltage for testing, a test fixture is highly recommended. New components purchased in quantity can be checked for value (such as resistors or capacitors) and other components such as LEDs, diodes, rectifiers, and transistors can be quickly checked for critical parameters. For example, if you buy resistors in quantity (100 for \$2) you can check them or match them quickly.

■ FIGURE 1. Grayhill clips with resistor.



BY W. HARTLEY ROBERTS

Simple test fixtures can be designed that hold one component. One of the older connector styles — banana jacks and plugs — works very well for making test fixtures. Dual banana jacks have a spacing of .75" between the two connectors — standard across many products such as meters and generators. Pomona makes adapters with this spacing, as do many other manufacturers, so building test fixtures with this spacing is recommended. Although the frequency bandwidth of this attachment method is limited to low frequency use (under a MHz), for testing components out of circuit, fixtures using banana jacks are satisfactory and very easy to use. **Figure 1** shows test clips made by Grayhill that allow quick insertion of two-lead components. A portable multimeter can be used with clips

■ FIGURE 2. Meter with resistor.



■ FIGURE 3. LC130 with cap.





■ **FIGURE 4.** LC130 in action.

capacitors, diodes, and inductors if the meter has appropriate scales.

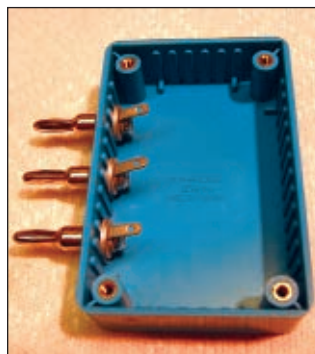
Test Fixture Examples

A test adapter for attachment to coaxial connectors is shown in **Figure 3**. Adapters like this have an advantage in that they eliminate the need for a lot of lead length from the measurement. So more accurate results can be obtained. **Figure 4** shows this adapter in action: A Tektronix LC130 capacitance meter is measuring a small capacitor. The marked value on the capacitor is 82 pF; the meter is indicating about 84 pF. Although the meter was zeroed before the measurement, the difference in reading could be from the component tolerance or the extra lead length of the capacitor. One side of the capacitor is at ground, so the lead length on



■ **FIGURE 5.** The drilled box.

like these to test components as shown in **Figure 2**. Measurements can be made on resistors,



■ **FIGURE 6.** Base with banana jacks mounted.

acceptable, and adapters like this really help.



■ **FIGURE 7.** Top components mounted.

that side is small. Meter calibration might be a factor, but for home use the tolerances are

A Simple Test Fixture

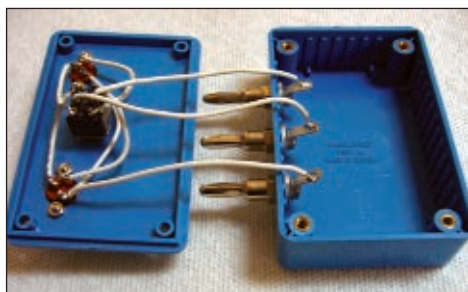
Fixtures quickly allow comparison of two devices to be constructed. Test adapters of this sort are often provided by manufacturers for their test instruments. Tektronix offered an adapter that would do this, but they are difficult to find and usually expensive. You can build a simple box with a switch and two connectors to serve this function. The fixture presented here is intended to permit attaching to a transistor/FET curve tracer.

A small plastic box is appropriate for this project. I used a blue plastic box to match the side cover colors used on older Tektronix instruments. **Figure 5** shows the plastic box prepared for receiving components to attach to a curve tracer. **Figures 6** and **7** show the components attached. (If you are using old stock components, be sure to clean the contacts before you try to solder to them. This is the voice of experience talking.

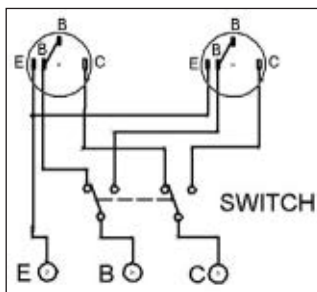
In **Figure 8**, the wiring has been completed. Since the emitters of the test devices are at ground, only the emitters and collectors need to be switched from one transistor to the other; a double pole double throw (DPDT) switch is required to accomplish this. The long lead lengths do not seem to present a problem in displaying parameter curves, because the curve tracer generator runs at 120 Hz. The schematic is in **Figure 9**.

The sockets used to construct this device were (new) old stock, and were built to provide

■ **FIGURE 8.** Our tester wired.



■ **FIGURE 9.** Schematic.



BILL OF MATERIALS

| ITEM | MFR PART # | DIST PART # |
|--------------------------|---------------------------|--|
| Plastic Box | Hammond 1591MBU | MOUSER 546-1591MBU BLUE |
| Switch (DPDT) | Mountain Switch MS-100737 | MOUSER 1081MD1T2B3M1QEEVX (or equivalent) |
| Test Clips w/Banana Jack | Grayhill 02-0 | ALLIED 9487397 |
| Banana Jack | 02-1 | ALLIED 9481000 |
| Transistor Sockets | Emerson 1080753102 | MOUSER 5301080753102. |
| | | www.mouser.com |
| | | www.alliedelec.com |

Obligatory Warning

If you acquire a curve tracer made by almost any vendor and perform testing on transistors, there will be the opportunity for the equipment to generate dangerous voltages. Since some curve tracers supply currents into the ampere range, combined with higher voltages, you must be careful not to exceed your limits. Happy testing!

connections for JEDEC TO-5 transistor packages and early in-line transistor configurations. They can be used later for long lead transistors (new stock) before they have been soldered. They can support JEDEC TO-18, TO-39, TO-92, and TO-100 packages, and other configurations. Lead diameter might be the only concern in using these sockets. If you build it and it doesn't work, check the usual suspects: cold solder joints, mis-wiring, or bad components. Your ohmmeter is your friend. Remember to check the switch contacts in relation to the bat handle before you wire.

Figure 10 is the completed test fixture. Although not very beefy, it is adequate for home use. You could construct a similar device for testing SCRs and power transistors with different sockets such as TO-220, a different switch, and a bigger box.

Figure 11 shows the test adapter in action on a 7CT1N plug-in installed in a 7000 series Tektronix oscilloscope. The transistor on the left is under test. Since Tektronix curve tracer models such as the 7CT1N and 575 have .75" spacing for input connectors, this fixture can perhaps be used on others.



■ **FIGURE 10.** The completed unit.



■ **FIGURE 11.** Our Tester on a Tektronix 7CT1N.

Test Complete

You will find that constructing test fixtures like this help to speed your projects along. They help eliminate errors from creeping into component selection and testing. If you have a large junk box full of components to check, test fixtures are nice to have. Setting up test fixtures for resistors, capacitors, or diodes will help you sort the junk box quickly. **NV**

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- 5Vdc operation, 65mA (typ): Receiver
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The Projects of **PROTOTYPE** **THIS**

With Joe Grand

avrsimon: A Do-It-Yourself Game Kit

Prototype This, an engineering entertainment program on Discovery Channel, offered a view into the real-life process of designing and building unique prototypes. In this 13 episode series which was filmed over the course of 18 months and aired starting in October 2008, we set out to tackle the problems of today by creating crazy, one-of-a-kind inventions of tomorrow. I was the team's electrical engineer and hardware hacker, and shared the screen with Zoz Brooks, a roboticist and software designer specializing in human-machine interaction; Mike North, a material scientist and mechanical engineer; and Terry Sandin, a special effects veteran. We were challenged to build things that had never been done before, looked cool on TV, and could be completed within the extremely tight financial and time constraints of television production. It was a fantastic adventure and great experience to say the least!

This quarterly series of articles will cover the electronic aspects of some of my favorite projects from the show. My hope is that you will be inspired, learn something new, or use my work as a building block for your own open source project. Let's begin!

Launched in 1978 by Milton Bradley, the addictive, flying saucer-shaped memory game of Simon remains an icon of early electronic games. The premise is simple: Repeat the sequence of lights and tones. This article presents my Simon clone running on an Atmel ATtiny2313, an eight-bit AVR microcontroller (**Figure 1**).

My implementation of the game combines a number of basic microcontroller functions such as reading switch inputs and turning LEDs on and off, with more complicated ones such as using sleep modes to extend battery life and playing sounds. I've also designed in a few gameplay enhancements such as no sound mode, fast mode, no LED mode, and reverse mode. Details of the original Simon design can be found in US Patent #4,207,087 entitled "Microcomputer controlled game" (www.google.com/patents/about?id=MAIyAAAAEBAJ&dq=4207087).

Full engineering documentation (including source code and PCB Gerber plots) is available on my website (www.grandideastudio.com/portfolio/avrsimon/). If you don't want to build the circuit from scratch, a kit is available from Parallax (www.parallax.com) and includes all of the necessary components, including a pre-programmed microcontroller and custom circuit board. The only additional items you'll need to build the kit are a soldering iron, solder, wire snips, and a battery.

Hardware

Like the original game, avrsimon's user interface is simple, comprising of four buttons, four LEDs, and a piezo

(All photos and figures by Joe Grand.)

buzzer for playing sounds. Refer to the schematic (Figure 2) and bill of materials (Table 1) for specific component information.

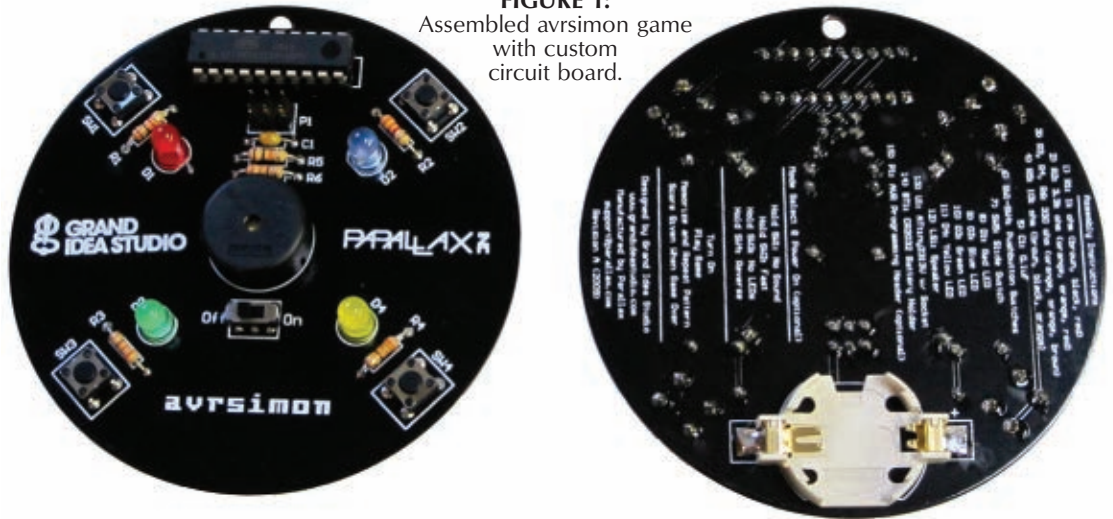
The Atmel ATtiny2313 microcontroller (www.atmel.com/dyn/products/product_card.asp?part_id=4660) is an eight-bit

microcontroller based on the AVR enhanced RISC (Reduced Instruction Set Computer) architecture. It features 2 KB of Flash, 128 bytes of in-system programmable EEPROM, 128 bytes of RAM, up to 20 MHz clock speed, 1.8V to 5.5V operation, and up to 18 general-purpose I/O pins all in a 20-pin package. Peripherals include two timers, four PWM channels, analog comparator, and a Universal Serial Interface/UART. It is a nice, low-cost part (around \$2 in small quantities) suitable for many embedded systems projects.

One side of each button (SW1, SW2, SW3, SW4) is connected to Port B 1, 4, 0, and 3, respectively. The other side of the buttons are connected to ground. The internal pull-up resistor (with a value between 20K and 50K ohm, according to the ATtiny2313 datasheet) is enabled on each of the Port B pins, removing the need for four external resistors. The buttons are active low, so the microprocessor normally sees a high signal ('1') — due to the pull-up resistor — when the button isn't being pressed. When a button is pressed, the microprocessor sees a low signal (0).

The cathodes of the four LEDs matching the four colors of the original Simon game (D1 red, D2 blue, D3

FIGURE 1:
Assembled avrsimon game with custom circuit board.



green, D4 yellow), are connected to Port D 0, 3, 1, and 2, respectively. A current-limiting resistor (R1, R3, R4, R2) connected to VCC is used in series with each LED to limit the amount of current allowed to flow through it which sets the brightness and prevents excessive current from damaging the LED. Like the buttons, the LEDs are active low and set up in a current sink configuration; meaning they will turn on when the output signal on one of the Port D pins is low (0). When we want to turn an LED off, we simply set the corresponding pin's output value to high (1). Each port pin on the ATtiny2313 can safely sink 20 mA which is well above what the LEDs on avrsimon require. When the red LED is on, it requires 1.3 mA, the green 3.0 mA, blue 0.13 mA, and yellow 3.2 mA.

One side of the piezo buzzer, LS1, is connected to ground and the other side is connected to Port B 2 via R6 — a current-limiting resistor. Instead of using the general-purpose I/O function as with the button inputs and LEDs, Port B 2 is used as its special function — Output Compare for Timer 0 — which outputs waveforms that will drive the piezo buzzer. Turning the game on and off is achieved with a simple slide switch used in an SPST configuration that connects and disconnects the battery supply from the

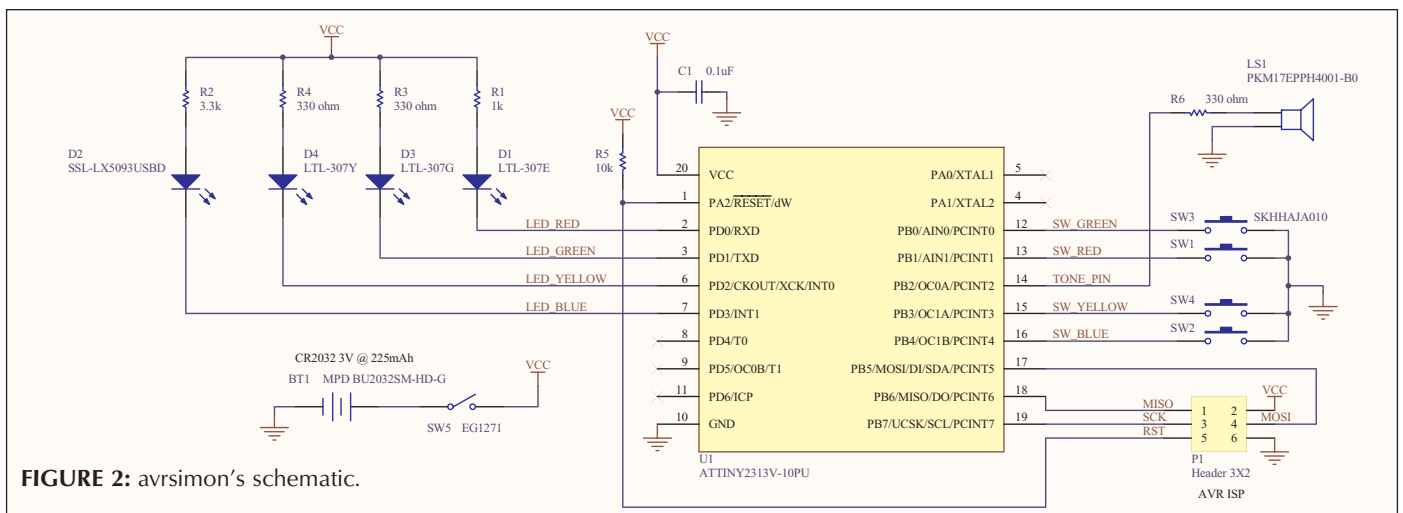


FIGURE 2: avrsimon's schematic.

VCC bus of the circuitry. The system is powered with a single CR2032 3V lithium coin cell which is easy to obtain from any local drugstore, convenience store, or electronics outlet. The CR2032 has a very nice current capacity for its size (20 mm in diameter) of approximately 225 mAh, although the lithium battery chemistry works best for applications requiring very low current discharge (tenths of mA) over months or years of use. Its maximum recommended continuous discharge is 3 mA which is what avrsimon draws during gameplay. When the game is not being used and while the system is waiting for a button press to begin a new game, U1 is placed into a sleep mode and current consumption is reduced to a scant 19.5 uA. With typical gameplay of a few hours a day, a single battery should last over a month.

There are a few other discrete components used in this design: C1 is a standard bypass/decoupling capacitor connected close to the VCC input of U1. R5 is a pull-up resistor connected to the active-low /RESET line of U1 that keeps the microcontroller operating properly (e.g., not resetting) unless the pin is intentionally pulled low. P1 is the standard six-pin AVR In-System Programming (ISP) header. This is an optional part that is only required if you plan on making changes to the firmware and want to reprogram U1 while it is in-circuit.

Firmware

At the highest level, the operation of avrsimon's firmware is straightforward:

Upon power-up, the hardware is initialized within the aptly named *hardware_init()* function which brings the system into a known state. The function configures the I/O pins (LED pins as outputs, switch pins as inputs), sets up the timers (Timer 0 is used for tone generation and Timer 1 for timeout counting used during gameplay), and enables the Pin Change Interrupt.

Then, *simon_config()* is called which sets the gameplay mode based on the combination of pushbuttons SW1-SW4 held down during power-up. If no buttons are pressed during power-up, then the game will play in the

normal mode. Other modes include no sound mode, fast mode, no LED mode, and reverse mode, and serve as an additional challenge for advanced users. Details of each special mode are discussed in the How to Play section of this article. After all configurations are complete, we move into the core *simon_game()* routine. Immediately after entering *simon_game()*, the system is configured to enter a low-power sleep mode and to awake on a button press from any of the four buttons. Sleep mode is attained by calling a specific sequence of functions/macros which define the type of sleep mode we want to enter, configure the interrupts, and then go to sleep:

```
// prepare to go to sleep/idle mode...
set_sleep_mode(SLEEP_MODE_PWR_DOWN);
cli(); // disable global interrupts
sleep_enable();
sei(); // enable global interrupts
sleep_cpu(); // now go to sleep to save power
```

Sleep mode conserves a significant amount of power by shutting down all unused modules of the microcontroller and only keeping the absolute essential features awake. In our selected Power-Down Mode (SLEEP_MODE_PWR_DOWN), all clocks and oscillators are disabled, all peripheral modules are turned off, and the only ways to awaken the device are via specific resets (external, watchdog, or brown-out), serial interface or INTO external interrupts, or a Pin Change Interrupt generated on specific port pins. For more details on sleep mode implementations, see www.nongnu.org/avr-libc/user-manual/group_avr_sleep.html.

With avrsimon, when a button press is detected via the Pin Change Interrupt on Port B 0, 1, 3, or 4 (corresponding to SW3, SW1, SW4, SW2, respectively), the system springs to life and begins the game.

The game itself is comprised of two core functions: *simon_play_moves()* and *simon_read_moves()*.

simon_play_moves() first pulls a number from *rand()* — a linear feedback shift register used as a pseudo-random number generator (<http://en.wikipedia.org/wiki/PRNG>) — which is seeded at the beginning of each game with the current value of U1's Timer 1 counter and whatever

| Qty | Reference | Description | Distributor/Part # |
|-----|--------------------|---|--|
| 1 | BT1 | Battery holder, CR2032 Lithium coin cell, SMT | Digi-Key, BU2032SM-HD-GCT-ND; www.digikey.com |
| 1 | C1 | 0.1 μ , 50V 10% bypass capacitor ceramic axial, X7R | Digi-Key, 1109PHCT-ND |
| 1 | D1 | 5 mm LED, red high-efficiency diffused, 19 mcd, 2.0V | Digi-Key, 160-1705-ND |
| 1 | D2 | 5 mm LED, blue diffused, 300 mcd, 3.5V | Digi-Key, 67-1751-ND |
| 1 | D3 | 5 mm LED, green diffused, 19 mcd, 2.1V | Digi-Key, 160-1706-ND |
| 1 | D4 | 5 mm LED, yellow diffused, 29 mcd, 2.1V | Digi-Key, 160-1703-ND |
| 1 | LS1 | Piezoelectric buzzer, 72 dB @ 25V pp, 4 kHz, PCB mount | Digi-Key, 490-4694-ND |
| 1 | P1 (optional) | Header, 3x2 vertical, male, PCB mount | Digi-Key, 3M9459-ND |
| 1 | R1 | 1.0K ohm, 5% 1/4W | Digi-Key, 1.0KQBKND |
| 1 | R2 | 3.3K ohm, 5%, 1/4W | Digi-Key, 3.3KQBK-ND |
| 3 | R3, R4, R6 | 330 ohm, 5%, 1/4W | Digi-Key, 330QBK-ND |
| 1 | R5 | 10K ohm, 5%, 1/4W | Digi-Key, 10KQBK-ND |
| 4 | SW1, SW2, SW3, SW4 | SPST momentary pushbutton switch, 100 gf, PCB mount | Mouser, 688-SKHHAJ; www.mouser.com |
| 1 | SW5 | SPDT slide switch, 300 mA, PCB mount, L = 2 mm | Digi-Key, EG1918-ND |
| 1 | U1 | AVR microcontroller, DIP20 | Mouser, 556-ATTINY2313V10PU |
| 1 | U1b (optional) | Socket, DIP20 | Digi-Key, 3M5465-ND |
| 1 | PCB | Printed circuit board | Parallax |

TABLE 1: avrsimon's bill of materials.

pushbutton was pushed to start the game. The number from `rand()` is limited from 0 to 3 (corresponding to one of the four possible LED colors on avrsimon) and then stored in U1's internal EEPROM — a non-volatile storage container with individual byte addressing — at the memory address equal to the current length of the sequence. The game then plays the entire sequence that is currently in its EEPROM, contiguously from address 0 until the end of the sequence is reached. For more details on EEPROM handling, see www.nongnu.org/avr-libc/user-manual/group__avr__eeprom.html.

The game then enters the `simon_read_moves()` routine which waits for the player to begin replaying the sequence. For each move in the sequence, the corresponding address of the EEPROM is read and compared with the player's input. If the values do not match, then the player must have pushed the wrong button and the game will end via the `simon_failed_input()` function. If the values do match, then the player pushed the correct button and the game proceeds to the next move in the sequence. If the player successfully repeats the entire sequence, the game jumps back to `simon_play_moves()` to add another move to the sequence and repeats the process until the game is over.

Sound

Tone generation is based on the xyloduino project (www.rocketnummernine.com/2009/03/27/xyloduino-simple-arduino-piezo-organ/) and modified to support arrays of octaves, notes, and durations in order to create melodies. Timer 0 — a hardware peripheral internal to U1 — is used as an eight-bit counter that will toggle the OC0A output pin (Port B pin 2) from low to high or high to low when the counter value (TCNT0) matches the value programmed into the Output Compare Register (OCR0A). The toggling of the output pin will generate a square wave at the desired frequency that is fed into the piezo buzzer LS1. The `play_note()` routine is passed the octave, note, and length of the sound. It configures the Timer/Counter Control Register (TCCR0B) and OCR0A accordingly, waits for the sound to be played, and then disables the counter:

```
if (note)
{
    TCCR0B = pre[(int)octave];
    // set the prescaler depending
    // on what octave is selected
    OCR0A = note >> (octave%2);
    // there are two octaves for each
    // prescale setting, so adjust
    // accordingly
}
delay_ms(length);
// play sound for specified length
TCCR0B = 0;
// turn off sound
```

In order to play a melody, a sequence of notes stored in an array must be played one after the next:

```
for (i = 0; i < STARTGAME_SND_SIZE
* 4; i = i + 4)
{
    // octave, note, length
    play_note(pgm_read_byte(startgame_
snd_p + i),
    pgm_read_byte(startgame_snd_p
+ i + 1),
    pgm_read_word(startgame_snd_p + i + 2));
    delay_ms(50); // pause in between notes
}
```

The four sounds generated on the original Simon were based on four primary notes of a bugle which sound “in tune” when played in any order. avrsimon closely mimics those notes (www.waitingforfriday.com/index.php/Reverse_engineering_an_MB_Electronic_Simon_game):

- Tone 1: Blue, 392 Hz (G note)
- Tone 2: Yellow, 330 Hz (E note)
- Tone 3: Red, 262 Hz (C note)
- Tone 4: Green, 196 Hz (G note)

Development Environment

avrsimon was developed on OS X using CrossPack for AVR (www.obdev.at/products/crosspack/download-de.html). Formerly known as AVR MacPack, the package contains the core compiler, debugger, and AVR-specific

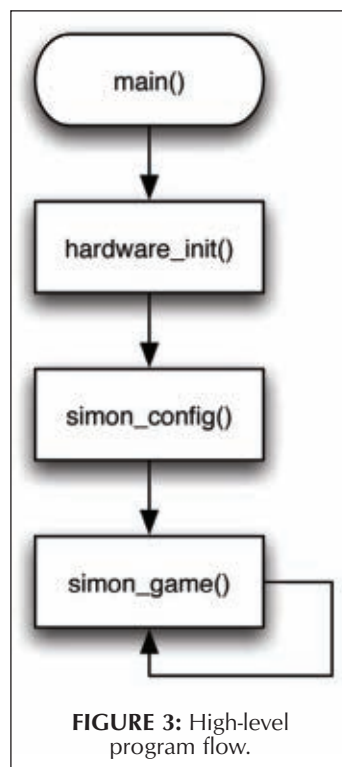


FIGURE 3: High-level program flow.

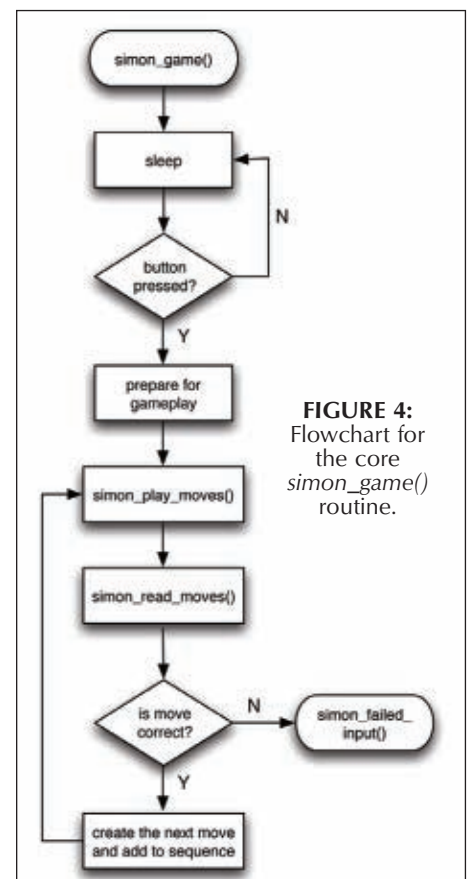


FIGURE 4: Flowchart for the core `simon_game()` routine.

tools, and integrates seamlessly with Apple's Xcode.

In-circuit device programming was achieved using an adafruit industries USBtinyISP interface (www.adafruit.com/index.php?main_page=product_info&cPath=16&products_id=46).

If you choose to modify avrsimon's firmware, you'll need to recompile the code and reprogram it into the microcontroller. To reprogram the microcontroller, hook up the USBtinyISP to P1 (insert and solder this optional six-pin male header onto avrsimon if you haven't done so already), locating pin 1 by its square pad on the backside of the circuit board. Then, open a Terminal window and go to your /firmware/ directory. Finally, run the *make install* command which launches the avrdude application twice with different parameters: once to load the compiled Hex file into Flash memory and once to set the device's configuration fuses (defined in the Makefile):

- 1) `avrdude -c usbtiny -p attiny2313 -U flash:w:main.hex:i`
- 2) `avrdude -c usbtiny -p attiny2313 -U hfuse:w:0xd1:m -U lfuse:w:0xe4:m`

For more information on Atmel AVR development, see:

- AVR Freaks web page, www.avrfreaks.net
- adafruit industries' AVR Tutorial web page, www.ladyada.net/learn/avr/

How to Play

In a nutshell, avrsimon gameplay is as follows:

- Turn On
- Play Game
- Memorize and Repeat Pattern
- Score Given When Game Over

When you first power up the game, a start-up tune will welcome you. Press any of the pushbuttons to start playing. The game will generate a sequence of lights and sounds that you are to repeat, starting first with a single element. After the sequence has been presented, simply press the button(s) corresponding to the LED that was illuminated and repeat the pattern. The sequence length will increment each time you successfully repeat the pattern, making the game increasingly more difficult as you go. The maximum sequence length is 255.

When your game is over, a short tune will be played, the correct LED in the sequence that you were supposed to have entered will be illuminated, and your score will be given by a series of blinking LEDs. The green LED corresponds to hundred; the red LED to ten; and the blue LED to one. For example, if you failed after a 13 element sequence, the red LED will first blink once and then the blue LED will blink three times.

avrsimon has a few optional twists to make gameplay more fun and interesting for advanced players. These special modes are selected by holding down one of the pushbuttons SW1-SW4 while first turning on the game (multiple pushbuttons can be held down at one time to create various combinations):

• SW1: No Sound/Quiet Mode

No sounds are generated while in this mode, making it perfect for gameplay late at night, in a library, conference session, or classroom.

• SW2: Fast Mode

This mode increases the speed of which the LED sequence is played and reduces the length of time allowed for you to repeat the sequence. Normally, you have five seconds to make a decision for each move. In fast mode, you're only allowed two.

• SW3: No LED Mode

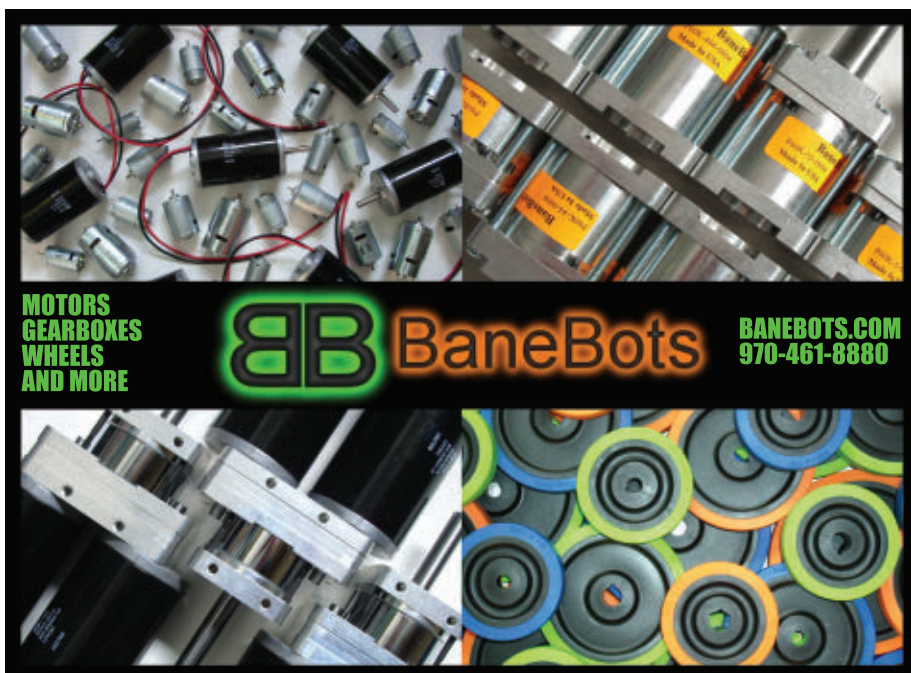
No LEDs are illuminated while in this mode. You'll have to repeat the pattern based on sound alone.

• SW4: Reverse Move

This mode operates like a FIFO (First In, First Out) stack in which you have to replay the sequence in reverse order (instead of repeating the exact order that the game presents).

To revert back to game's normal mode of operation, simply power cycle the unit. Enjoy the game! **NV**

Joe Grand is an electrical engineer, hardware hacker, and president of Grand Idea Studio, Inc. (www.grandideastudio.com), where he specializes in the invention, design, and licensing of consumer products and modules for electronics hobbyists. He can be reached at joe@grandideastudio.com.



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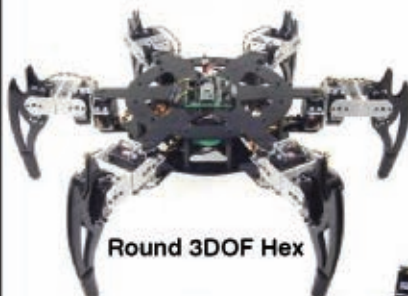
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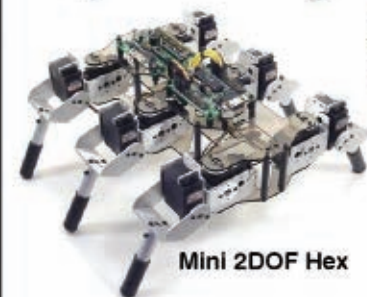
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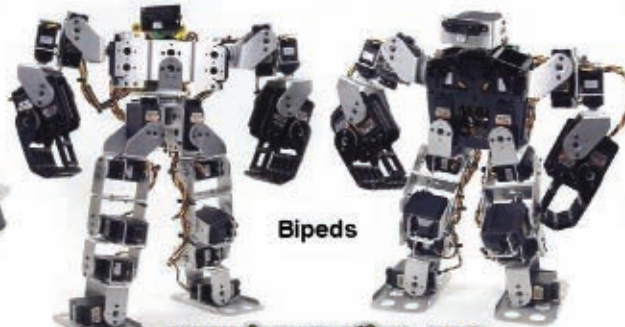
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Experiments with Alternative Energy

Part 8 – Introducing the WindPitch Wind Turbine

By John Gavlik, WA6ZOK

To continue our experiments with wind, this time I'm going to introduce you to the WindPitch™ wind turbine (Figure 1). It's unique in that most wind turbines of this size are just a combination of a simple DC motor connected to a set of fixed propeller blades that maybe light an LED when they are spinning. Basically, they're just a toy and possess no real educational value. The WindPitch is far more than that, however.

Like our Whirlybird™ wind turbine, the WindPitch has a small but powerful three-phase AC alternator and variable pitch blades (thus the name). The blades are actually designed to aircraft standards, so it is a superb electrical and mechanical teaching tool. Horizontal axis wind turbines (HAWTs) are currently the standard wind technology mechanism for grid-based electrical generation. You see them everywhere — generally with three blades that slowly rotate into the wind to make non-polluting power. What you don't see from a distance are the myriad factors that go into modern HAWT design and construction. That's what I want to

show you now with the WindPitch, so let's get started.

HAWT and VAWT Technologies

Previously, we worked with the Whirlybird wind turbine which is a VAWT (vertical axis wind turbine). The WindPitch is a HAWT since the axis of rotation of the propeller blades and the alternator shaft are parallel — or horizontal — to the ground. Unlike the Whirlybird, the WindPitch blades produce “lift” just like an aircraft wing or propeller (which is also a set of wings itself). This provides for a faster spin rate of the blades with the attendant increase in generated alternator power. Compare this with the “drag” blades of the Whirlybird that are basically pulled around by the wind with no speed amplification.

There is also the ability to adjust the pitch of the blades to match the particular wind conditions. Wind is generally of higher speed at higher altitudes (even just a hundred feet or so off the ground), so the ability to control the pitch angle of the blades into the wind becomes important. Modern commercial wind turbines can quickly adjust the blade pitch to accommodate slowly varying wind speeds, as well as sudden wind gusts or lulls. This is done to extract the maximum electrical power from the wind for any given condition and to protect the wind turbine from

damage should it encounter a sudden wind blast that could send it spinning out of control (even momentarily).

Another thing a HAWT needs is a wind vane to keep the propellers pointed into the wind at all times. However, commercial wind turbines are generally installed into the prevailing wind to begin with, and use more sophisticated electronic and mechanical techniques to constantly adjust for minor changes in wind direction so a vane is not necessary. The WindPitch does have the traditional vertical wind vane.

A HAWT is typically mounted on a tower — unlike a VAWT that is



Figure 1. The WindPitch HAWT.

generally mounted on the ground. The advantage of this is that the wind is stronger and steadier at higher altitudes and doesn't suffer from surface interface that can both slow the wind speed and create turbulence. The drawback is that the tower itself must support all the weight of the turbine assembly, along with the forces generated by the spinning blades — not to mention its own weight and air resistance. The tower is also an obstruction to the laminar wind flow that can cause the blades to momentarily lose power and slow down as they rotate parallel to the tower. When spinning, this causes a pulsing action like a misfiring engine cylinder that disturbs the smooth blade turning action and imparts additional mechanical stresses on the whole thing.

The important thing to understand here is that the HAWT is now the commercial standard for “big wind” grid-based operations, mainly because the cost-performance ratio is higher than with an equivalent VAWT to generate the same electrical power. You will, of course, see successful examples of vertical axis machines for small wind applications for which they are perfectly suited (like for a house or small buildings; see the **sidebar**). Just like the choice between AC and DC electricity, one isn't necessarily better than the other, and each variety of wind turbines (vertical, horizontal, or hybrid) has its own niche and should be viewed in terms of choice of application as opposed to better or worse. For the remainder of this section, refer to **Figure 2** for an example of the major components that go into a commercial HAWT.

The WindPitch in a Nutshell

Figure 3 shows the major components of the

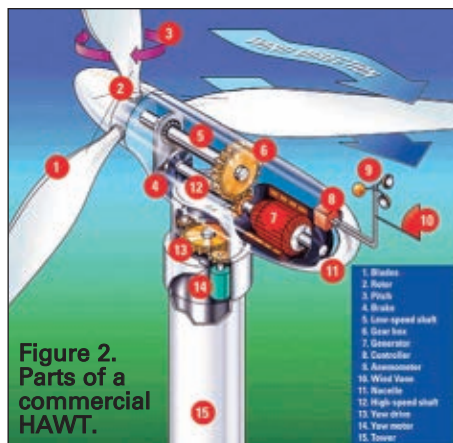


Figure 2.
Parts of a
commercial
HAWT.

WindPitch wind turbine. Generally, it consists of a three-blade propeller arrangement mounted to a hub where the blades can be manually adjusted for pitch by the hub mechanism (**Figure 4**). The hub then “pushes on” to the shaft of the three-phase alternator that is mounted at the inside-front of the streamline fuselage plastic housing. The hub along with the blades can be removed to change blade types; there can be anywhere from two to 12 blades (**Figure 5**).

The vertical wind vane is mounted at the opposite end of the fuselage to keep the blades pointed into the wind. The entire assembly is mounted on an aluminum pipe whose opposite end is inserted into a weighted base to keep the turbine steady with wind blowing across the blades. The small tab that protrudes from the bottom of the fuselage and inserts into the top of the pipe allows it to “wobble” back and

Small Wind VAWT

These are just two examples of VAWT for homes and buildings. Depending on their size and mounting location, they can provide from a few hundred watts to several kilowatts of power.

Photo credit: PacWind and Wikipedia.



forth in a yawing motion to capture the changes in wind direction, while a small set screw holds it to the pipe so it doesn't fly away.

The most distinctive feature is the hub (**Figure 6**) that is designed to accommodate up to twelve blades and can also adjust the blade pitch. Once the blades are mounted into the hub, you are able to adjust the blade pitch simply by rotating what is called the Blade Pitch Controller. A

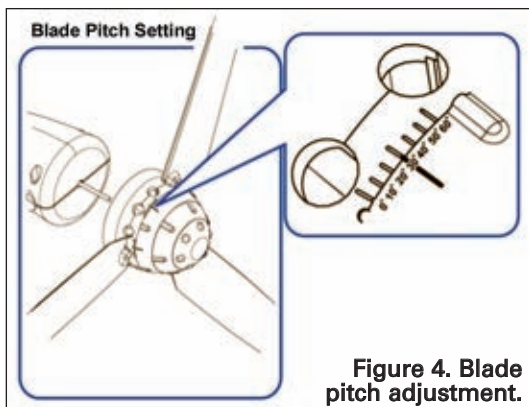
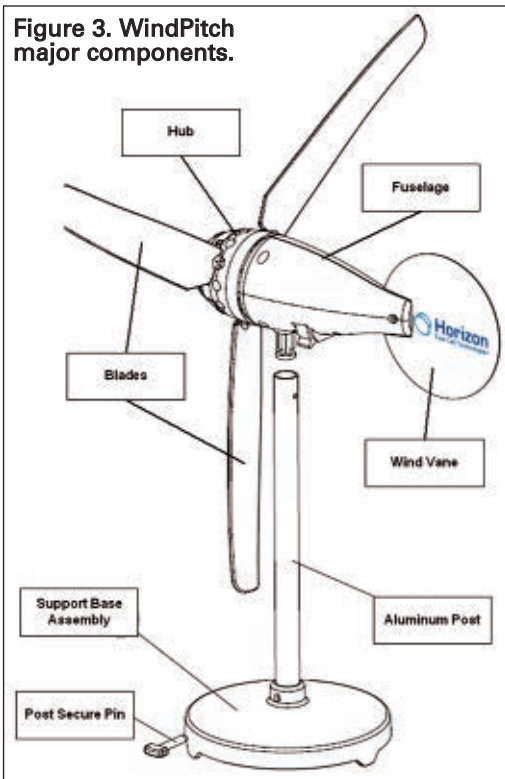


Figure 4. Blade
pitch
adjustment.

Figure 3. WindPitch
major components.



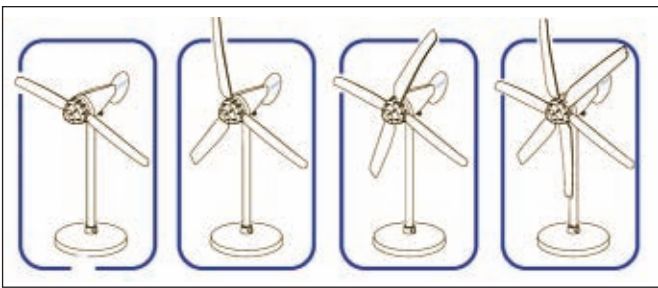


Figure 5. Possible blade arrangements.



Figure 7. Hub assembly pieces with blades.

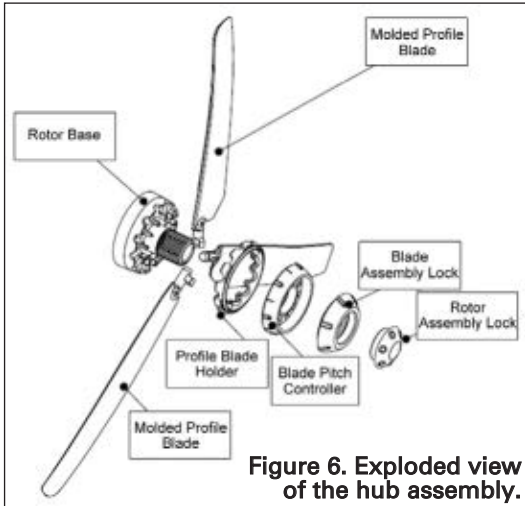


Figure 6. Exploded view of the hub assembly.

clockwise/counter-clockwise turn rotates the blades to a new pitch angle (**Figures 4 and 7**), and then another couple of twists of the Blade Assembly Lock and Rotor Assembly Lock secure the new pitch angle in place. Overall, this is a well thought out device from top to bottom and is a pleasure to work with.

Blade Characteristics

The fundamental element that is different from our Whirlybird wind turbine is that the WindPitch sports

actual aircraft-type blades that provide lift that “pulls” them into the wind, as opposed to being “pushed” around by it. The blades are – in effect – really wings with the same characteristic shape of an aircraft wing. As seen in **Figure 8**, a wing deflects the air moving past it such that the upper part of the airflow generates a lower pressure, as compared with the lower part thus imparting “lift.” However, the question still remains, “How is lift created?”

This from the well-known Bernoulli Principle and the lesser known Coanda Effect

(see the **sidebar**) where air tends to follow a curved surface as long as the curvature isn’t too exaggerated or the “angle of attack” (the steepness of the blade edge as it is presented to the moving wind) isn’t too great. If either happens, the laminar (smooth) airflow is disturbed and turbulence is created that can lead to a stall.

Propeller blades exhibit the same lifting and stalling characteristics as fixed aircraft wings. Helicopters are a prime example of propeller blades that are really rotating wings where blade shape and pitch control the motions

of the machine. However, in our case we are using the moving wind to spin the blades instead of powering the blades themselves; the effect, however, is still the same. Lift is generated to help power the blades in their spinning motion and, thus, impart more power to the three-phase alternator.

Blade Types

The WindPitch comes with three groups of distinct blades that are designated as BP-28, NACA 44, and NACA 63 types. NACA stands for the National Advisory Committee for Aeronautics which was created in President Woodrow Wilson’s days. In 1958, they were absorbed by (the then new) NASA – the National Aeronautics and Space Administration. The older acronym-based blade descriptions still remain to this day.

As I mentioned earlier, the WindPitch is not a toy, and the adherence to these blade standards is one example of its rigorous nature.

Figure 9 illustrates the profiles of each of the three blade shapes that are generally distinguished by the amount of material used on their windward sides. Time and space limit any further discussion regarding airfoil shapes and characteristics; however, our experiments will demonstrate how each profile has its own set of behavioral characteristics that make it suitable for varying wind conditions.

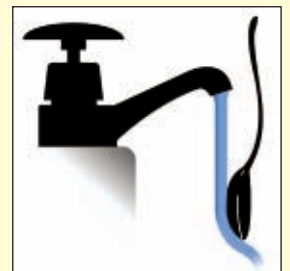
Hub Assembly

As **Figure 6** illustrates, a great deal of thought was devoted to the

The Coanda Effect



Though the Bernoulli Principle explains the source of lift in an aircraft wing, on or about 1930 a French engineer by the name of Henri Coanda (1866-1972) discovered another effect that plays an even larger role in producing lift. The Coanda Effect states that a fluid or gas stream will hug a convex contour when directed at a tangent to that surface. It can be demonstrated by placing the back of a spoon against a running stream of water. The pattern of the water will conform to the spoon’s curve. If you hold the spoon so that it is free to swing, you should be able to notice that the spoon is actually being pulled towards the stream of water. The same effect occurs with an airplane wing. If the wing is curved, the airflow will follow the curvature of the wing. Thus, wind turbine blades designed to aircraft standards also conform to the Coanda Effect.



multi-part hub that holds the blades and allows them to swivel. Adding from one to 12 blades is possible, including mixing and matching different blade types. One begins by selecting the blades of choice, then placing them in the Rotor Base, followed by holding them in place with the Profile Blade Holder. The other three parts of the hub assembly (the blade pitch controller, blade assembly lock, and rotor assembly lock) are then screwed onto the Rotor Base forming a completed assembly as shown in **Figure 7**. By partially unscrewing the rotor assembly lock, you can adjust the blade pitch and then lock it in place again (**Figure 4**).

Blade Pitch

Besides blade shape and the number of blades used, blade pitch is right up there on the list for how to best generate power based on wind speed. Blade pitch or simply pitch refers to adjusting the angle of attack of the blades of a propeller into or out of the wind to control the production or absorption of wind power. The hub allows up to a 90 degree pitch angle. For reference, a zero degree pitch angle [with the flat part of the blades parallel to the wind] is called the “stall angle.” In effect, the blades are acting as a complete barrier to the wind in this position. The other extreme is with the blades at a 90 degree angle with only their leading edge facing the wind. This is called furling or feathering, and presents the minimum surface area to the oncoming wind.

Blade pitch control is a feature of nearly all commercial horizontal-axis wind turbines. While operating, a wind turbine’s control system adjusts the blade pitch to keep the rotor speed within operating limits as the wind speed changes. Feathering the

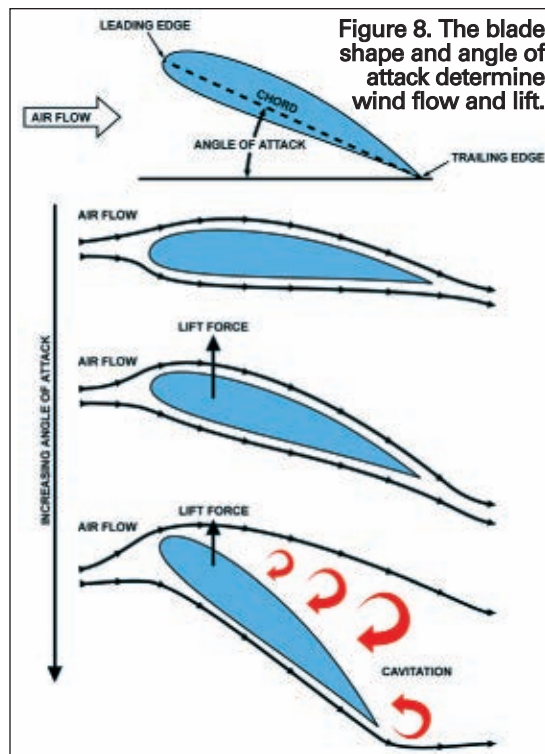


Figure 8. The blade shape and angle of attack determine wind flow and lift.

blades stops the rotor during emergency shutdowns or whenever the wind speed exceeds the maximum rated speed. During construction and maintenance of wind turbines, the blades are usually feathered to reduce unwanted rotational torque in the event of wind gusts.

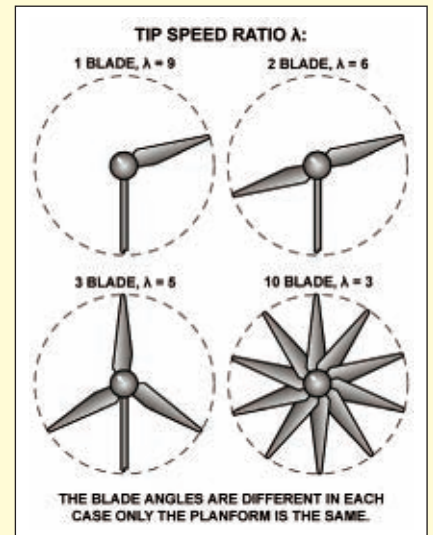
In an aircraft blade, pitch is usually described as “coarse” for a high angle of attack and “fine” for a low angle of attack. The same is true for wind turbines. Blade pitch is normally described in units of distance/rotation (assuming no slip) and is much like the gearing of a car’s transmission. Low pitch yields good low speed acceleration, while high pitch optimizes high speed performance and economy. Because the velocity of a propeller blade varies from the hub to the tip (called Tip Speed; see the **sidebar**), the blade must be formed correctly in order for the pitch to remain constant along the length of the blade.

Number of Blades

Since most commercial wind turbines use three-blade

Tip Speed Ratio

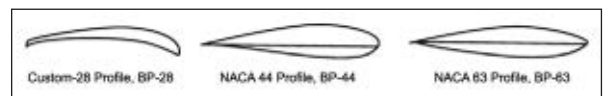
Tip Speed Ratio is the ratio between the rotational speed of the tip of the blade and the actual velocity of the wind. High-efficiency, three-blade turbines have tip speed ratios of 5-7. The tip speed ratio determines how fast the wind turbine will want to spin and so has implications for the alternator that can be used. On the whole, a high tip speed ratio is better, but not to the point where the machine becomes noisy and highly stressed.



propellers, you might automatically assume that three blades are the optimum number. In fact, the number of blades is a compromise based — once again — on wind conditions and aesthetics. The number of blades involves design considerations of aerodynamic efficiency, component costs, system reliability and aesthetics (see the **sidebar**). In addition, noise emissions are affected by the location of the blades upwind or downwind of the tower, and the speed of the rotor. Given that the noise emissions from the blade’s trailing edge and tip vary by the fifth power of blade speed, a small increase in tip speed can make a huge difference.

Wind turbines developed over

Figure 9. WindPitch blade types.



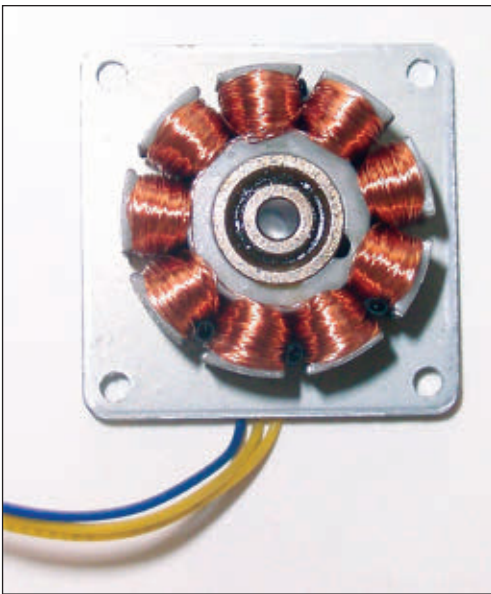


Figure 10. Three-Phase AC alternator internal mechanism.

the last 50 years have almost universally used either two or three blades. Aerodynamic efficiency increases with the number of blades, but with diminishing return. Increasing the number of blades from one to two yields a six percent increase in aerodynamic efficiency, whereas increasing the blade count from two to three yields only an additional three percent in efficiency. Further increasing the blade count yields minimal improvements in aerodynamic efficiency and sacrifices too much in blade stiffness as the blades become thinner. We will do some experiments on this to confirm if the WindPitch exhibits behavior

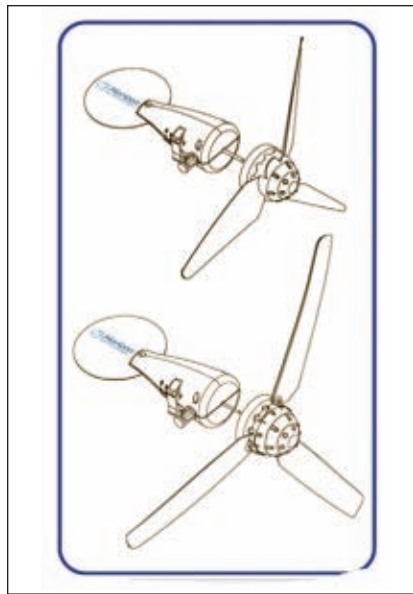


Figure 11. Attaching blades to the alternator shaft.

close to these same efficiencies.

System reliability is also affected by blade count, primarily through the dynamic loading of the rotor into the drive train and tower systems. While aligning the wind turbine to changes in wind direction (yawing), each blade experiences a cyclic load at its root end depending on blade position. This is true of one, two, three blades, or more. However, these cyclic loads when combined together at the drive train shaft are symmetrically balanced for three blades, yielding smoother operation during turbine yaw. Turbines with one or two blades can use a pivoting teetered hub to nearly eliminate the

cyclic loads into the drive shaft and system during yawing.

Finally, aesthetics can be considered one of the biggest factors in determining blade count, since most people find the three-bladed rotor is more pleasing to look at as opposed to a one or two bladed rotor. All these are reasons why modern wind turbines use three blades.

The Three-Phase Alternator

Switching from blade theory and design to the WindPitch power plant, I mentioned at the beginning the WindPitch uses a three-phase alternator (**Figure 10**) rather than a simple DC motor. The primary advantages of alternators are no commutator and increased power output due to the three-phase architecture (refer to Part 7 for background on three-phase versus single-phase advantages).

The alternator is permanently wired in the STAR configuration, so I won't be able to do any STAR versus DELTA comparisons, but with a three-phase alternator ALL the electrical power is delivered directly to the rectifier circuit with nothing lost through the mechanical and electrical resistance of a commutator. In the WindPitch, the alternator is inserted inside the plastic fuselage with its shaft protruding from the front and attaching to the rotor hub (**Figure 11**).

Number of Blades

Three-bladed turbines are not a magic number as these photos point out.

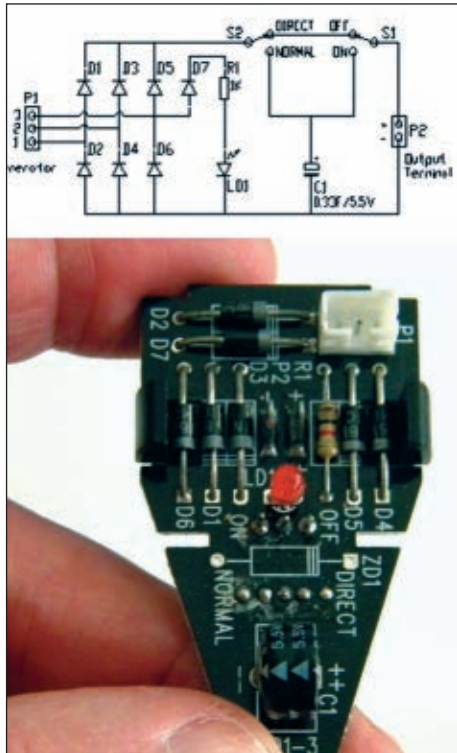
The 98 meter diameter (longer than a football field), two-bladed NASA/DOE Mod-5B wind turbine was the largest operating wind turbine in the world in the early 1990s. Like the Spruce Goose of the 1940s, it too is an exaggerated example of what can be done with a particular technology. *Photo credit: Wikipedia.*

The NASA Mod-0 research wind turbine at Glenn Research Center's Plum Brook station in Ohio tested a one-bladed rotor configuration. Its odd looks probably contributed to its lack of popular acceptance even though its one blade may have proven effective for its design goals. *Photo credit: Wikipedia.*



The Full Wave Rectifier Circuit Board

The three wire output of the three-phase alternator is connected to a six diode, full wave rectifier board (**Figure 12**) that converts the three-phase AC voltage into unfiltered DC. This is the exact circuit that I showed you with the Whirlybird in Part 7 where you learned about the advantages of three-phase full wave rectification and how a three-phase full wave rectifier works. The rectifier



diodes are mounted on a triangular circuit board that fits behind the alternator; the rectified DC output is available on two (positive and negative) spring-loaded connectors. Suffice it to say that the WindPitch wind turbine delivers a very powerful electrical output for its model size which, of course, is dependent on the wind applied to the blades. We will get into this in our experiments.

Wrap-Up

The experiments I have planned for the WindPitch will take another article to complete. The goal of this article was to introduce you to the theory and operation behind HAWT technology; so in that regard, here is a list of factors that affect the HAWT power output:

- **Blade Swept Area:** This was described in Part 7 with the Power Formula. Refer back to determine how to compute this value with the given blade area. I'll cover it again in our next article when we experiment with the WindPitch.
- **Blade Shape:** This provides the aerodynamic lift that pulls the blades into the wind instead of just having the wind drag them around.
- **Blade Pitch:** This is the angle that's best for startup and for maintaining optimum power output under varying wind conditions.

Figure 12. Full wave rectifier circuit board and schematic.

Noteworthy ...

Website Changes: Our www.learnonline.com website is now strictly dedicated to online learning matters, so I've recently moved all of our REEL Power products and Experimenter Kits information to our new website at www.EnergyEducationLab.com. Please make a note of this.

Acknowledgements: This article is an original work by the author; however, credit for portions of it including selected text and images go to Wikipedia.

Credits: The WindPitch is a product of Jointiff, LTD and Horizon Fuel Cell Technology (www.horizonfuelcell.com). I want to thank MT Poon of Jointiff and Dane Urry of Horizon for their assistance and guidance in preparing this article.

- **Number of Blades:** This determines the overall efficiency coupled with performance of the turbine.
- **Wind Vane:** This keeps the blades pointed directly into the wind at all times.
- **Three-Phase Alternator:** This is significantly more powerful and efficient as compared with a DC commutator-based motor.
- **Tower Height:** This is important in capturing smoother wind for better laminar flow across the blades which improves power output.

Next time, I'll demonstrate some interesting experiments using the WindPitch. So, until then conserve energy and "stay green." **NV**

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Serial Communications: Part 3

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by Joe Pardue

Recap

This will be the last part of our mini series on serial communications between a PC and the Arduino. We will do two things this month. First, we will use what we learned in the last two articles about C# .NET programming to build an Arduino voltmeter that displays ADC data on the PC. Second, we will introduce the FT232R device that the Arduino board uses to mediate serial communications. For this device, we will learn how to use some of the extra FT232R pins, and we'll look at how the Arduino uses this device to automatically reset the board.

Arduino Voltmeter

Using the Arduino Voltmeter

A word of warning for those who think running with

scissors is a good idea. The Arduino voltmeter hooks directly to the Arduino analog input pin 0 which can measure up to five volts. **THIS CIRCUIT IS NOT PROTECTED IN ANY WAY.** It will not forgive you doing something stupid like trying to measure the voltage in the wall socket. If you survive such a Darwinian experiment, your hardware won't and that could include the PC you've got your Arduino hooked up to (most USB ports are protected, but you can never be absolutely certain).

The Arduino Software

The Arduino voltmeter running on the PC (shown in **Figure 1**) is communicating with the following AVR_Test program running on the Arduino:

```
// AVM_Test
// Joe Pardue December 17, 2009
// based on Tom Igoe's example in the
// Arduino Serial.print(data) documentation

void setup()
{
    // begin the serial communication
    Serial.begin(19200);
}

// variable to hold the analog input value
int analogValue = 0;

void loop()
{
    // read the analog input on pin 0
    analogValue = analogRead(0);

    // print as an ASCII-encoded decimal
    Serial.print(analogValue, DEC);

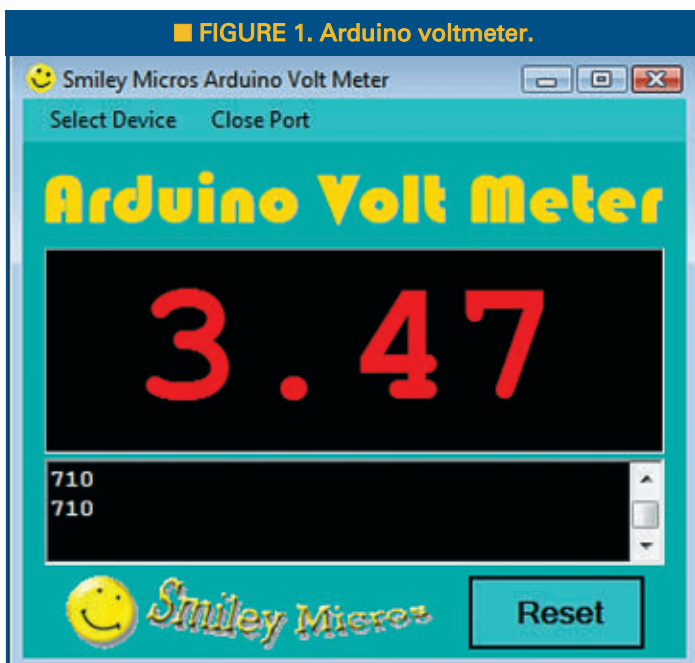
    // print a terminal newline character so the
    AVR Voltmeter
    // will know that it has received the full
    string
    Serial.print('\n');

    // delay 1 second before the next reading:
    delay(1000);
}
```

The PC Software

The Arduino voltmeter (AVM) source code in C# is provided in Workshop20Source.zip and requires Visual

■ FIGURE 1. Arduino voltmeter.



Studio Express .NET to open and run it. [This can be downloaded from the *Nuts & Volts* website; www.nutsvolts.com.]

The program is built from many of the components used for the Simple Terminal discussed last month. You access the Arduino by clicking the 'Select Device' menu item, which then opens the Settings dialog as shown in **Figure 2**.

The AVM uses the .NET Serial Port control Readline() function that returns a string, which is defined as a sequence of characters terminated by the '\n' character. The Arduino sends the ADC value and then a '\n' character (as shown in the source code) so that the AVM will interpret the input as a string. The AVM will then display the ADC value in the lower text window and convert that value into a voltage that it displays as a big fake red LED display in the upper window. The voltage is calculated from the ADC value using:

```
// Calculate volts
myVolts = ((Double)myADC * VoltsPerADC);
```

Based on the constants:

```
static Double maxVoltage = 5.0;
static Double maxADC = 1023.0;
Double VoltsPerADC = maxVoltage /
maxADC;
```

Voltage Across Resistance

Let's use this with a circuit and play with Ohm's Law. We put 10 of the 1K Ω from the Arduino Projects Kit on the breadboard so that they are each connected in series. Then connect one end of that series to +5V and the other end to the GND as shown in **Figure 3** and **Figure 4**. [This arrangement of resistors is called a voltage divider.]

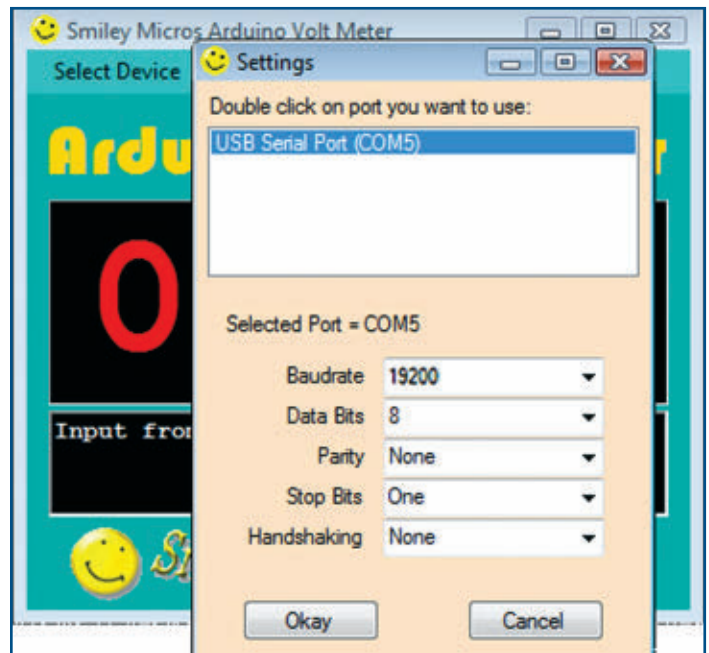
Figures 3 and 4

show the Arduino Analog Input pin 0 attached between the third and fourth resistors closest to the +5V end.

We know that Ohm's Law is Voltage (V) is equal to Current (I) times Resistance (R):

$$V = IR$$

(And if 'we' don't know this already, then take my word for it.) We also know that we have five volts



■ FIGURE 2. Select your Arduino.

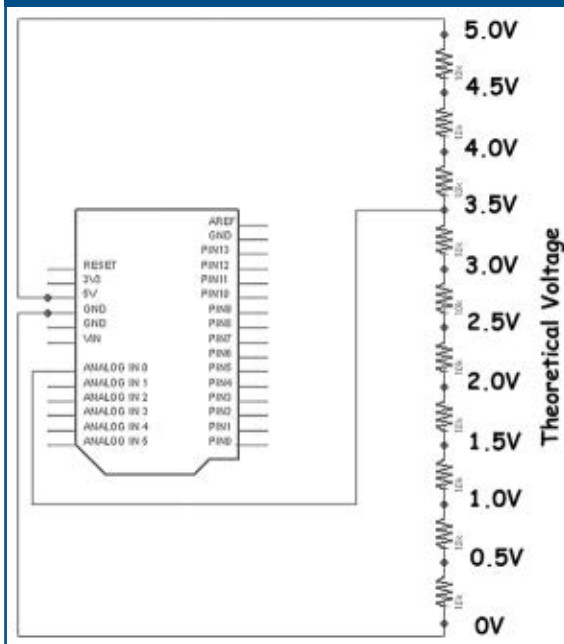
and a total of 10K Ω resistance in our circuit, so we can use a little beginning algebra to calculate the unknown variable, current (I):

$$I = V/R$$

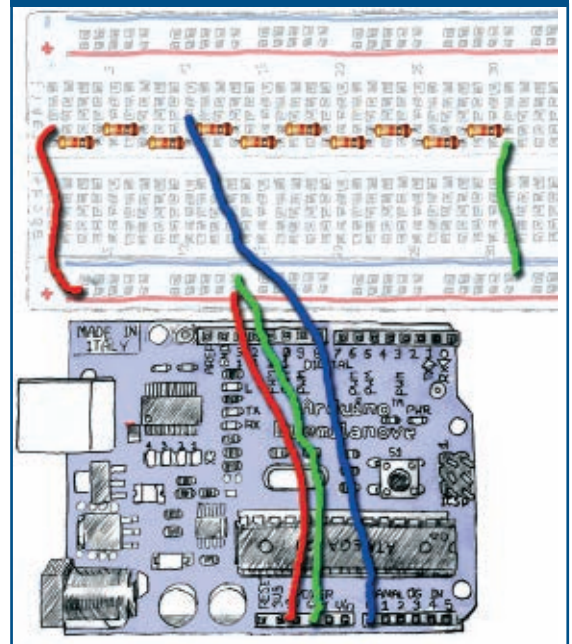
$$I = 5/10000 = 0.0005 \text{ amps}$$

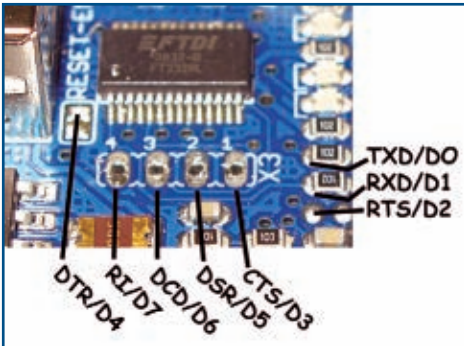
0.0005 amps is the same as 0.5 milliamps which we will usually show as 0.5 mA. So, we have 0.5 mA current running through each of the 10 resistors. Since each resistor is 1K Ω and we can solve Ohm's Law for

■ FIGURE 3. Schematic - resistors in series.



■ FIGURE 4. Layout - resistors in series.





■ FIGURE 5. FT232R on the Arduino Duemilanove.

$$V = IR$$

$$V = 0.0005 * 1000 = 0.5 \text{ volts}$$

So, theoretically, we should be able to measure the voltage between the seventh and eighth resistor above 0V and it should conform to Ohm's Law where the total resistance of the seven resistors is 7K Ω :

$$V = IR$$

$$V = 0.0005 * 7000 = 3.5 \text{ volts}$$

I ran the Arduino voltmeter as shown in **Figure 1** and got 3.47 volts.

Okay, 3.47 isn't equal to 3.5, but it is about as close as we can expect with a setup like this. Our resistors only claim 5% accuracy, so each one can be plus or minus 50 Ω and, again using Ohm's Law we see:

$$R = V/I$$

$$R = 3.47/0.0005 = 6940 \text{ } \Omega$$

And 6940 is actually pretty darn close since 5% of 7000 Ω is 350 Ω — our theoretical error — but we are only 60 Ω off. Your results will vary a bit but should be within a similar range.

Building the Arduino Voltmeter in C# Express.NET

By this point in your PC-serial-GUI-development-using-C# career, and assuming you built the projects in the last two columns, you should be able to build the Arduino voltmeter GUI just by looking at **Figure 1** and winging it. You may not have seen such things as how to make the textbox text white and the background black, but you should be familiar enough with our chosen tool that you can

| Modem Line | FT232RL Pin # | Arduino PCB | GPIO D-Bus |
|------------|---------------|-------------|------------|
| TXD (out) | 1 | TX | D0 |
| RXD (in) | 5 | RX | D1 |
| RTS (out) | 3 | R2 | D2 |
| CTS (in) | 11 | X3 - 1 | D3 |
| DTR (out) | 2 | RESET_EN | D4 |
| DSR (in) | 9 | X3 - 2 | D5 |
| DCD (in) | 10 | X3 - 3 | D6 |
| RI (in) | 6 | X3 - 4 | D7 |

■ FIGURE 6. FT232R pins on the Arduino.

the voltage across each resistor:

going to go off the high board.

Introducing the FT232R

As we've seen, the Arduino is not a single thing but a toolset that consists of (among other things): a hardware board, a PC IDE (Integrated Development Environment), and a communications link between them. Let's take a look at the communications hardware that intermediates between the USB on the PC and the USART on the Arduino: the FTDI FT232R.

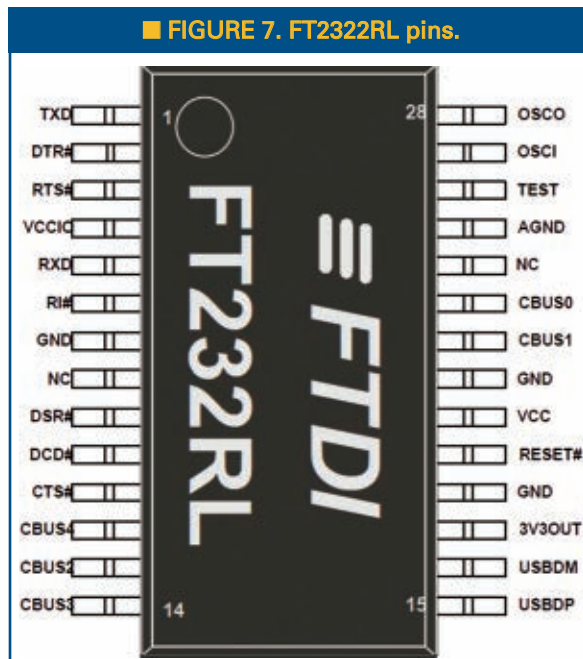
After all this time playing with the Arduino hardware, you might not have realized that the Duemilanove board has two microcontrollers on it. In addition to the general-purpose Atmel AVR ATmega328 that we've been spending all our time on, there is a special-purpose FTDI FT232R USB UART IC (www.ftdichip.com/Products/FT232R.htm) that controls our serial communications between the Arduino and the PC (see **Figure 5**).

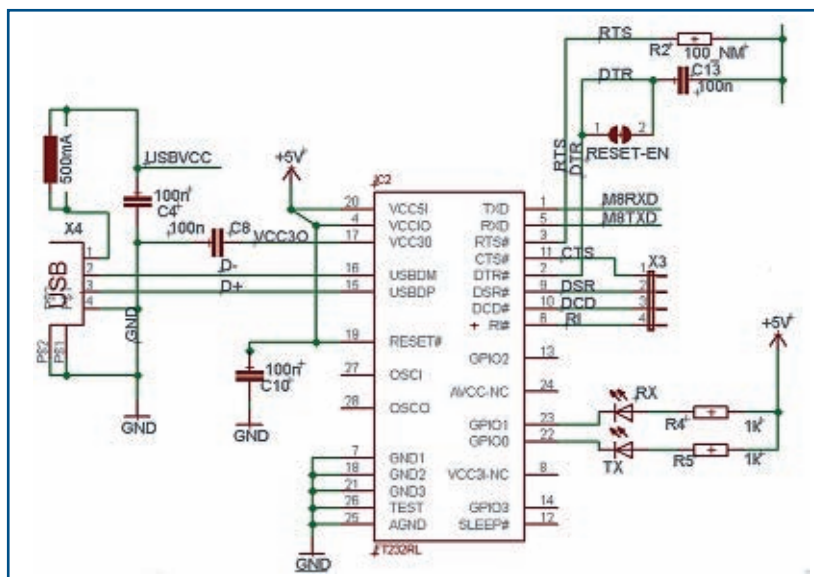
I first discussed the FT232R in *Nuts & Volts* (before there even was a Smiley's Workshop) in the Jun '08 article: 'The Serial Port is Dead: Long Live the Serial Port.' That article discussed the concept of a Virtual Serial Port over USB using the FTDI chip FT232R on a breadboardable PCB — the BBUSB. This powerful little device is also the basis for my book *The Virtual Serial Port Cookbook* and an associated hardware projects kit available from *Nuts & Volts*.

The pins on the FT232R have at least two possible uses for each pin. Eight of the pins can be used as modem lines for converting USB to RS-232 style UART signals; these pins can also be used for GPIO (General-Purpose Input Output) as the eight-pin DBus. Four other pins can be used as the CBus or for special functions such as to blink LEDs when you have UART traffic as is done on the Arduino to blink the Tx and Rx LEDs. We will look at using some of the more accessible FT232R pins in both the modem and GPIO modes.

Let me repeat some praise

■ FIGURE 7. FT232RL pins.

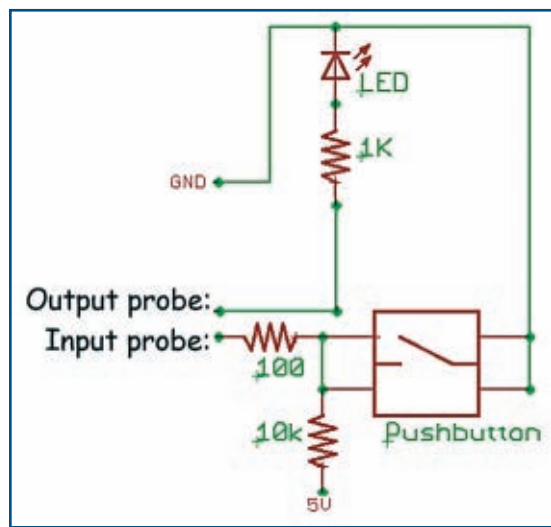




■ FIGURE 8. FT232RL in Arduino schematic.

about the Arduino: It is a really good thing for beginners that you can use it without knowing anything about the FT232R (or bootloaders, or WinAVR, or AVRdude for that matter). We, however, are well beyond that beginner phase and are going deeper so that we can make our system even more useful. In addition to the USB pins, there are five other pins of the FT232R that the Arduino uses when communicating with the PC. They are: pin 1 TXD (transmit); pin 5 RXD (receive); pin 22 and 23 to blink the Tx and Rx LEDs; and pin 2 DTR (Data Terminal Ready). Check out **Figure 8**. That last one may be a bit of a surprise, but it is used off-label to reset the Arduino so that you can automatically upload code from the Arduino IDE to the AVR. The DTR pin resets the AVR so that the bootloader becomes active at the same time the Arduino IDE activates the program AVRdude to upload the code.

Okay, so why is it called DTR and not 'reset'? Well, that is because it is actually one of eight modem pins on the FT232R that are part of the concept of a virtual RS-232 serial port from a USB. Many serial ports on microcontrollers ignore all but two of these (RxD and TxD), and a few use a couple of other pins. It is rare to find any system that uses them all, so you'll usually have extra pins to play with. If you read 'The Serial Port is Dead ...' article, this will all make more sense. For now, let's just say that DTR has a long and interesting history but for our purposes it is a pin that we can use in the modem mode to toggle from the PC using old-fashioned serial port commands (in our C# example, we set this pin to 1 with `serialPort1.DtrEnable = true`; and to 0 with `serialPort1.DtrEnable = false`), thus providing a signal to the AVR reset pin that will force the AVR to jump to the bootloader so that we can upload a program.



■ FIGURE 9. Circuit to probe input and output.

There are also other modem pins (see **Figure 6**) available on the FT232R that with a little effort you can get at on the Arduino board. Four of these are easy to use since they are brought out on the X3 connector shown in **Figure 5**. A table of these pins is shown in **Figure 6**. [FYI, the pinouts for the FT232RL used by the Arduino are different from those shown in the 'Serial Port' article which uses the FT232RQ.]

In case this isn't entirely clear, let me repeat: We can use some of the FT232R pins in the modem mode for off-label uses such as using DTR for resetting the Arduino, or we can use the pins for general-purpose I/O. When we use them in the modem mode to communicate between the PC and the Arduino they can only be used for input or output as shown in the table. However, when used in the bus mode, they can either input or output (but not serial communications). NOTE: YOU CAN'T USE BOTH THE MODEM AND BIT-BANG MODES AT THE SAME TIME.

Accessing the FT232R Pins

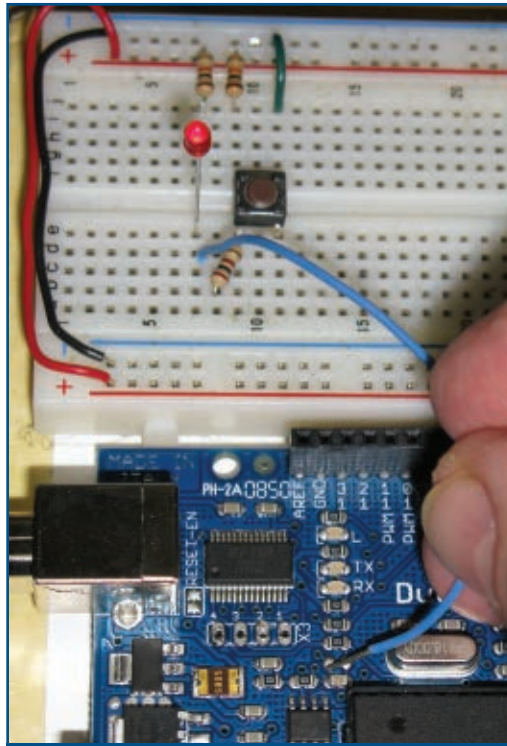
Before proceeding with these experiments, I strongly suggest you remove the ATmega328 from its socket to protect it from possible damage (use a small flathead screw driver and gently pry it up a little on each end until it pops out). All of the FT232R pins can be accessed the hard way by directly attaching wires to the FT232R pins (tiny wire, microscope, fine-tipped soldering iron, patience of Job — (not Steve, but the Old Testament guy)). Since we aren't either Job, I suggest we forgo the temptation and limit ourselves to probing the pins individually as we test them. We can probe the FT232R pins using the schematic shown in **Figure 9**. And by probe, I mean a random piece of wire as shown in **Figure 10**, where I use the RTS output to light up an LED.



Modem Mode

Using the Pin Change Tester Application

In order to light up that LED, you'll need some PC-side software that lets you set and clear the RTS line. I wrote a little program in C# as shown in **Figure 11** that lets you toggle the output on RTS and DTR while also reading the input on the CTS, DSR, DCD, and RI lines. You will find the Pin Change Tester C# source code in the Workshop20Source.zip file. I didn't generate this as a separate application so you will have to run it in Microsoft Visual C# Express Edition which is okay since you want to see the code anyway, don't you? Plug your Arduino into the PC USB port, then run the Pin Change Tester program. Use the Settings menu item to open the port as shown last month for the Simple Terminal.



■ FIGURE 10. Wire to RTS controls LED.

is reading. If you set it for output, then you can click the on/off buttons in the middle row to turn the associated pin on or off, allowing you to use your probe as shown in **Figure 10** to light up an external LED. Also notice that the D0 and D1 pins are the same as the TX and RX, and are brought out on the Arduino female header pins 0 and 1, so these are the easiest to access.

Cool! I just got my first Vista BSOD (Blue Screen Of Death). I was running the bit-bang test code and then tried to open the same device in Developer Terminal *just to see what would happen*. Now I know that my laptop with dozens of programs open can burn all the way down to the foundations and with a simple restart, it can survive. However, I almost didn't when my system crashed (I'm sure my blood pressure went off the charts while

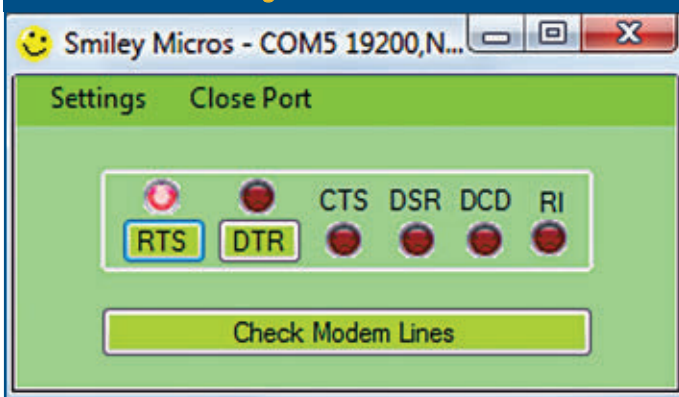
Bit-bang Mode

To test the FT232R pins in the bit-bang mode, we will once again go to the 'Serial Port' article and use the Bit-bang Test program. The C# source code is included in the Workshop20Source.zip file, not as an application but as a project that you can open in Visual Studio .NET Express. You can repeat the probe tests you did previously, but this time each pin is not forced to be an input or output but can be used as either (depending on how you set the pin in the D bus block on the program). Click the button as shown in **Figure 12** to set each pin as either input or output. If you select input, then the associated LED at the bottom will become active and will either light up or dim down, depending on the state it

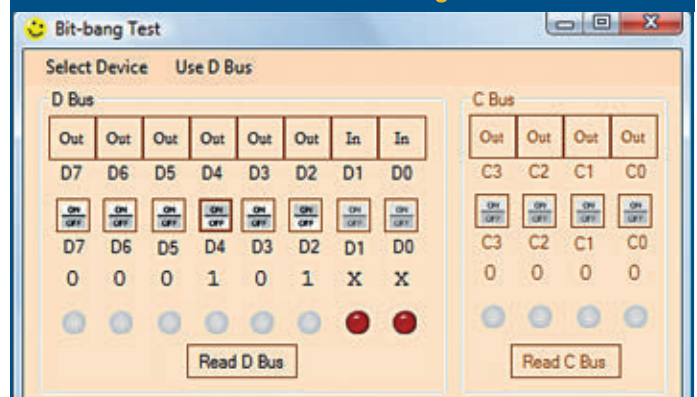
I was waiting to see how much work I'd lost). End of story: I saved everything right before I did the tests with my C# programs because I had a slight fear that maybe the idiot who wrote the code (me) might try something dangerously stupid. Moral: Before using any of my code, make sure you have backed everything up, saved your recent work, have your heart medications handy, and have the time to wait for Windows to figure out how to come back from the dead.

Okay, having a BSOD is a terrible way to end a workshop, but sometimes you have to face the fact that this stuff can get weird quickly. If, however, you have come to embrace the weirdness and want to look deeper, then you might want to get the Arduino Projects Kit and *The Virtual Serial Port Cookbook* and associated projects kit available from Nuts & Volts. **NV**

■ FIGURE 11. Pin Change Test: Click RTS to turn LED on or off.



■ FIGURE 12. Bit-bang Test.



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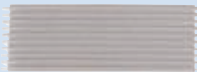
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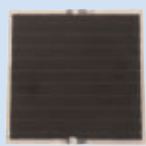


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■ BY FRED EADY

MAKING A MESH OF THINGS

Just as FedEx was delivering electronic parts for a future Design Cycle column, a man with a couple of healthy pipe wrenches appeared behind the delivery representative. The wrench-laden stranger identified himself as an employee of my natural gas supplier. As it turned out, Chris placed a box of SMT parts in my hand and the gas company's wrench handler left me with a brand new gas meter. All of this may seem routine. However, my new gas meter no longer requires a pair of human eyes to ogle its needles. Before any of us called them "network nodes," electronic devices participating in a network were normally connected to each other with wire. Some folks with pointy hats also joined the networking fray, connecting their network devices together with RF. Even with RF, ancient network nodes usually could not depend on their neighbors to help them get their messages back to base. I can't speak for my new gas meter, but as far as getting a message back to headquarters, I'll bet it has the ability to get by with a little help from its "friends" in the neighborhood. This friendly association is called mesh networking. Thank goodness Ringo didn't have a clue about mesh networking. Can you imagine the lyrics, "I get by with a little help from my mesh."

VE_MESH

Today's mesh topologies have already left wired networks in the dust. Point-to-point RF networks are also being choked out by mesh networking. There is more than a handful of mesh networking variants out there right now. With that, our attention this month will focus on the Diversity Path Mesh topology which is a product of Virtual Extension. Diversity Path Mesh technology appears to use "bad" network methods to its advantage.

Every node in a Diversity Path Mesh wireless network is analogous to an ant. No ant in the colony is unique except as to what it has been programmed to do. I'll bet that ants don't have names or numbers assigned to them physically and neither do VEMesh Nodes. As you will see, nodes in a Diversity Path Mesh wireless network depend on neighbor nodes and the overall network application just as ants in a colony depend on each other and the queen.

A major portion of the idea behind mesh networking

is to eliminate wire. Yet another portion of mesh networking is all about servicing wireless remote sensors and wireless remote sensor networks. The presence of sensors sometimes requires the presence of sensor controls. So, if we sum all of the parts, a wireless mesh network can be defined as a means of wirelessly controlling and monitoring a remote sensor network.

When I work with any type of radio equipment, the first question that comes to mind is the effective range of the equipment I will be using. Many of us think the range of a radio set is totally dependent on the power of the transmitter. Not so. There are a multitude of factors that affect the range of a wireless mesh network node. On the transmitter side, range depends on the efficiency of the antenna system and the environment that the wireless network node must exist within. Walls, metal doors, buildings, terrain, and any type of metal structures are all potential range busters in a wireless mesh network topology. Even vegetation is a range-hampering concern at the frequencies used by most networks. In addition to

having sensitive front end circuitry, receiving nodes in a wireless mesh network must also be able to cope with propagation path cross talk and radio frequency interference caused by Earthly phenomena or other magnetic wave emitting devices competing for the same RF air space. Believe it or not, range in a wireless mesh network is also affected by the way the data is encoded and transmitted.

VEmesh is based on Diversity Path Mesh technology. If we were asked to define Diversity Path Mesh, the words would go like this. Diversity Path Mesh is a multi-hop bi-directional communications method that was specifically developed for wireless sensor networks that operate in the unlicensed frequency bands.

Recall that I mentioned that Diversity Path Mesh seems to use “bad” network practices to its advantage. Instead of routing data through the network, Diversity Path Mesh floods the network with data. Flooding occurs when a transmitting node transmits the same message to every node in the network that is within range. Thus, in a Diversity Path Mesh wireless network every node in range receives the same message. With every node receiving the same data, there is no need to include any routing data in the transmitted message. No routing information in the packet results in a smaller message. The absence of the requirement for physical addressing also results in a reduction of complexity in the node’s hardware design. Since every node receives the same message and there are no routing tables to maintain and update, Diversity Path Mesh network nodes can be added and removed with zero disruption to data transfer within the network.

Despite the advantages of flooding, simultaneous retransmissions can result in collisions that must be reconciled with additional retransmissions, which must be corrected with more retransmissions, and so forth. When transmission corrections overtake data throughput, the network falls into chaos resulting in what is termed a storm. Diversity Path Mesh eliminates chase-your-tail transmission storms in the network by relaying messages to surrounding nodes in predetermined controlled time slots. The multiple identical transmissions in a Diversity Path Mesh-based wireless network are summed at the receiving node in the receiver’s demodulator. The summing of the identical incoming messages results in an increase of the received signal strength. With every node in the network using this coordinated

simulcast method, multiple transmission paths to the destination are created.

These methods bring increased reliability to the network in that there is no single path of failure. Dead spots in a wireless mesh network are also eliminated due to the creation of multiple transmission paths.

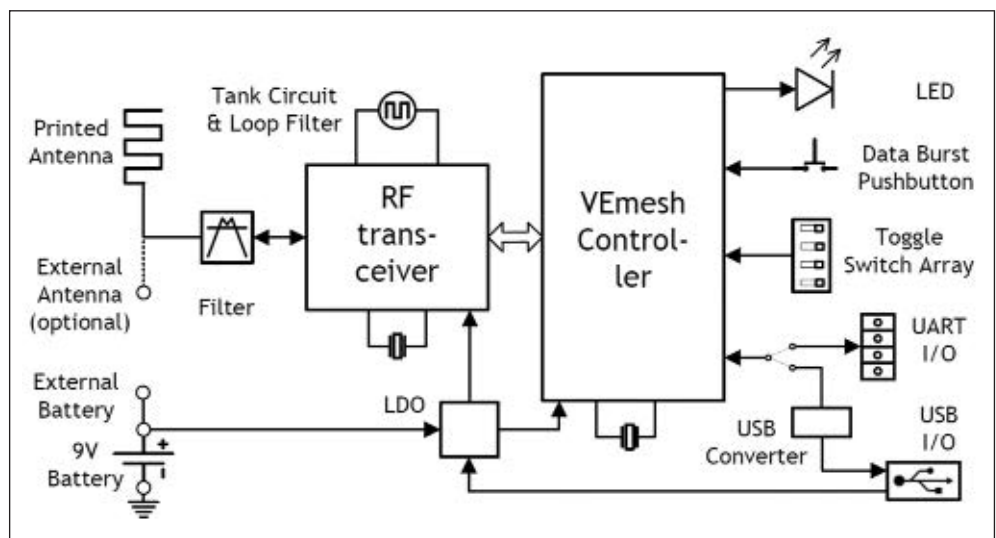
As you have probably already ascertained, the nodes are the network. Thus, physical routers and routing information within the data packets are eliminated. With no routing requirement, an unlimited number of nodes can be inserted and removed at any time without network disruption, data throughput is high, and internodal range is enhanced due to the use of simultaneous parallel paths. Is this too good to be true?

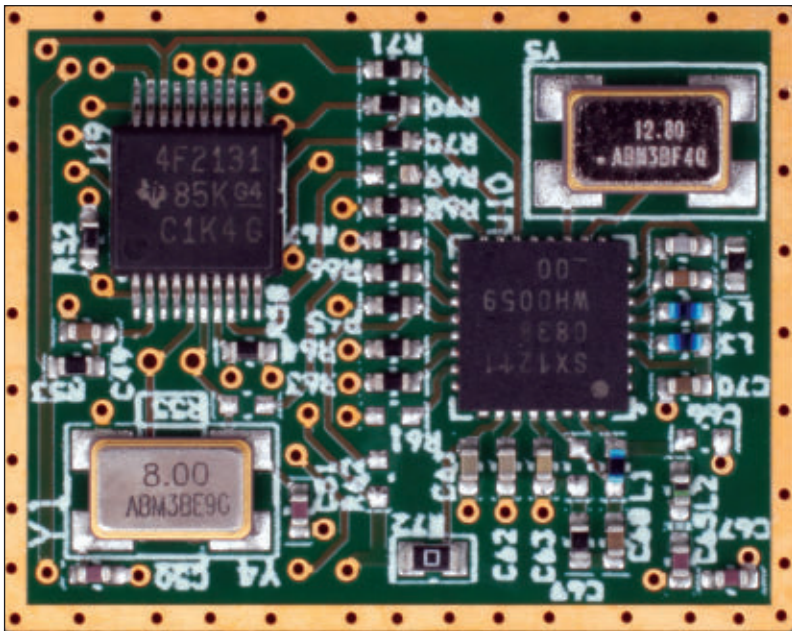
VE MESH 101

I just happen to have a Gateway and some VEmesh nodes from which we can assemble our own test network. To expedite our testing, the VEmesh nodes I have are evaluation versions which are loaded with supporting hardware and firmware specifically installed to facilitate an easy to set up test network configuration. For instance, the output power of the evaluation nodes is fixed at 10 mW. In reality, the output power of a VEmesh Node can range from -10 to +20 dBm (0.1 mW to 100 mW). The nodes also contain a toggle switch array in the guise of a four-position DIP switch which allows a quick way to change the operating mode and address of the node. You already know that Diversity Path Mesh network nodes don’t have unique addresses. So, VEmesh Node addressing is only used in a specific evaluation mode. The other extras found on a typical evaluation node are shown graphically in **Figure 1**.

The VEmesh Gateway is responsible for corralling all of the data and command messages for processing by the management application. The VEmesh Gateway does exactly what its name implies. All messages that flow out of the management application find their way through the Gateway first. The same is true for any messages that are

■ **FIGURE 1.** The VEmesh controller runs the show with the assistance of a radio and a pair of data I/O interfaces. The radio is equipped with an on-board printed circuit board antenna; power distribution is under the control of an LDO regulator.





■ **PHOTO 1.** There's no sense in trying to pick out who's who in this shot as we can't alter the operation of the radio or the VEMesh controller. Trust me. This is the business end of a VEMesh Node and Gateway.

in our possession are limited to UART and USB interconnects. UART-enabled VEMesh Nodes are designed to interface to a sensor's output via the Node's RS-232-based interface. The Nodes with a USB portal are intended to be connected directly to a PC USB port which is emulating a standard PC COM port. The protocol of choice is RS-232 EIA serial data transfer using TTL logic levels. The VEMesh evaluation Nodes and Gateway are preprogrammed for a baud rate of 19200 bps.

The heart of a VEMesh Node is under the lens in **Photo 1**. I figure the radio IC is to the far right of the shot as I can trace paths from the UART interface directly to the Texas Instruments part on the left.

inbound from the wireless sensor network nodes — the Gateway sees it first. A message can be data, a command, or a response to a command.

While a VEMesh Gateway's job is to interface wireless sensor network traffic to a host management application, the VEMesh Node is born to do the down and dirty work. VEMesh Nodes interface directly to a sensor or sensor array, and are responsible for relaying data between nodes and to and from the host management application.

Almost any type of sensor communications interface can be adapted to a VEMesh Node. The evaluation nodes

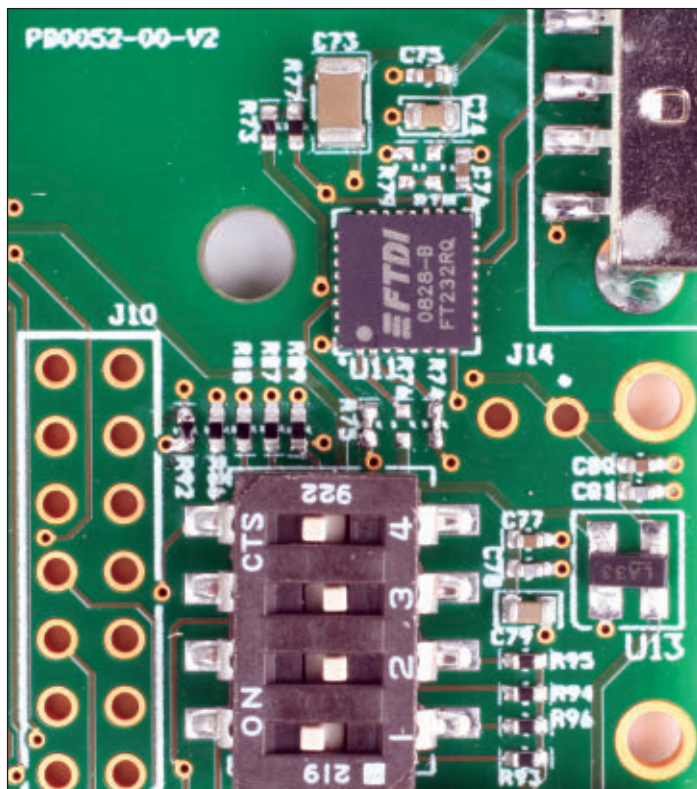
THE VEMESH NODE HARDWARE INTERFACE

The VEMesh Node's UART interface consists of a UART_RXD input, a UART_TXD output, and a UART_CTS output. The aforementioned UART signals are located on the Node's J10 connector as pins 4, 6, and 8, respectively. Pin 10 of J10 is the UART interface ground connection. A macro view of J10 is shown in **Photo 2**.

All of those USB discussions we've had in past Design Cycle offerings have paid off in that we already know how the FTDI FT232RQ USB interface IC you see in **Photo 2** works. In this case, the USB interface is used to turn the VEMesh Node's UART interface into a USB interface that is supported by a PC COM port. The inclusion of the USB interface allows us to use a terminal emulator program such as Tera Term Pro to imitate the output of a sensor that would normally be attached to the VEMesh Node. The evaluation firmware loaded on the Nodes and Gateway is coded to allow the transmission and reception of one to 20 ASCII characters. The end of the ASCII string is delimited with a Carriage Return (0x0D) and Line Feed (0x0A) character pair. ASCII character transactions allow us to use Tera Term Pro to send data via a PC keyboard and receive results in human readable form.

VEMESH EVALUATION OPERATIONAL MODES

There are two VEMesh Node operating modes that we can select with the four-position toggle switch array. Standard mode is as close to a real-world VEMesh wireless



■ **PHOTO 2.** The VEMesh Node UART interface is pinned out on J10. Note the use of an FTDI USB interface IC for the PC connection.

■ **PHOTO 3.** This is an aerial shot of the full VEmesh Node that we took pot shots from in Photos 1 and 2. Note the activity LED and Data Burst Pushbutton along the bottom of the shot.

network as we can get with the evaluation Nodes and Gateway. The second mode is called Echo mode which exists for evaluation purposes only.

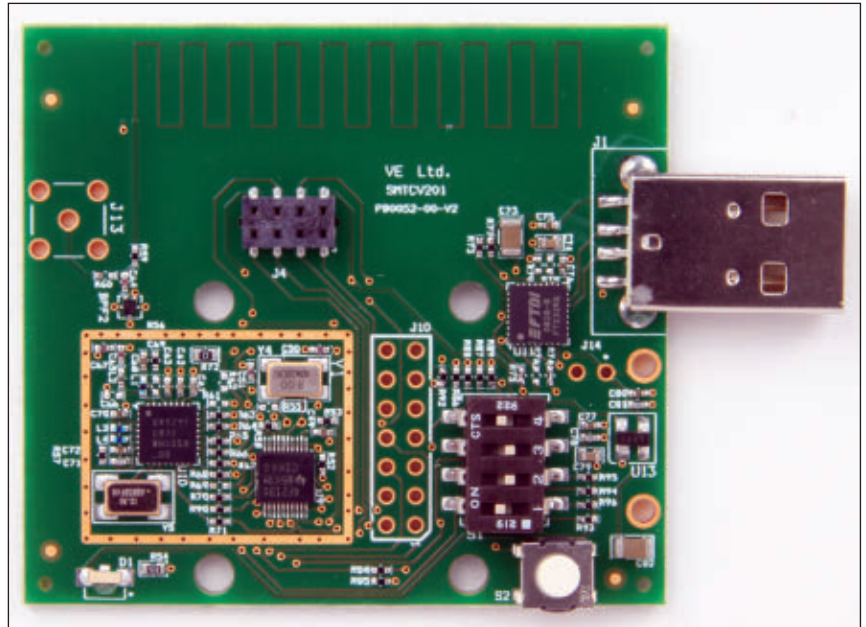
Echo mode demands that a VEmesh Node retransmit (echo) any message it receives from the Gateway back to the Gateway. The echoing of the message is done in lieu of transmitting any sensor data the addressed Node may have queued. This is where the USB PC connection comes into play. The terminal emulator program running on the PC is used to transmit an ASCII character string and display the results echoed by the addressed VEmesh Node.

Just in case you're wondering why Echo mode is not part of a standard VEmesh wireless network, recall that VEmesh Nodes do not have physically assigned addresses. Thus, it is up to the host management application to uniquely identify the Nodes in the network using their data streams. The Gateway and Nodes are not aware of any embedded addressing information as messages are simply passed from node to node, to gateway, and finally to the management application. This implies that the addressing information must be embedded into the message and is only meaningful to the host management application. Since the addressing information is not hard-coded into any VEmesh Node, we must emulate an embedded address that would normally be inserted into the sensor-initiated message transmitted by a Node. We do this with hexadecimal patterns we click into the toggle switch array.

If you apply a binary address pattern to the four toggle switches in the toggle switch array, you will end up with addresses 0 through 15 (0x00 through 0x0F hexadecimal). Address 0 (zero) is not really an address as when selected, the VEmesh Node on which it resides enters Standard mode. Our Node in **Photo 2** is set to echo the message addressed to VEmesh Node 9.

PUTTING ECHO MODE TO THE TEST

To test the Echo mode operation, I installed the Windows XP FTDI VCP (Virtual COM Port) driver and the Tera Term Pro terminal emulator application on a Lenovo S10 Netbook. Following the software install, I plugged the VEmesh Node you see in **Photo 3** into one of the Lenovo Netbook USB ports. I attached the Gateway to a second similarly equipped Lenovo S10 and started a Tera Term Pro session for the USB-installed VEmesh Gateway. At this

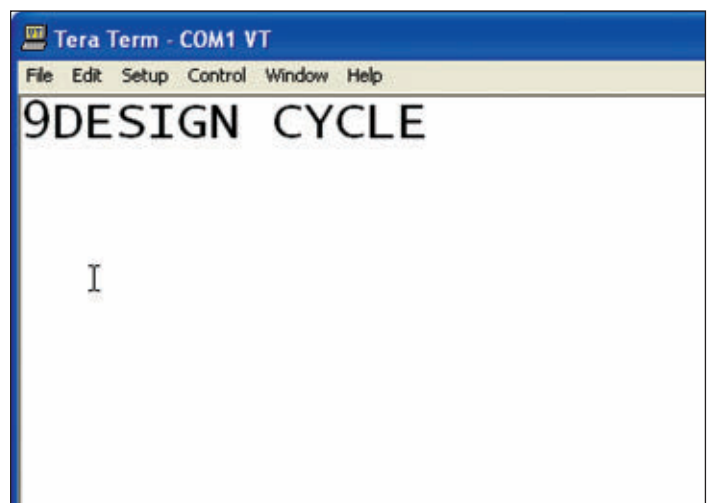


point, both the Node and Gateway activity LEDs began to flash, indicating that they were synchronized and in contact with each other.

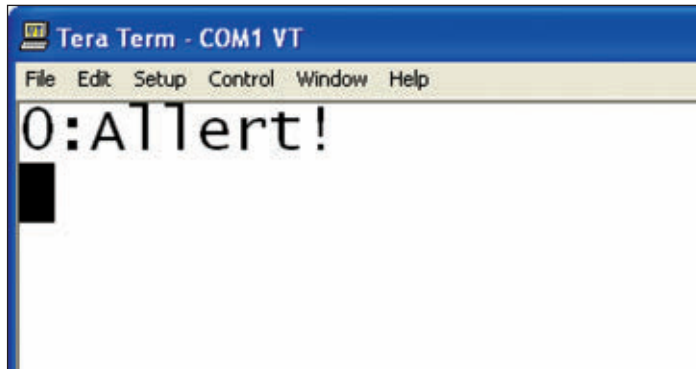
The syntax for Echo mode is to send the selected VEmesh Node address followed by an ASCII string terminated with a CRLF (0x0D 0x0A) sequence from the VEmesh Gateway. I did just that using a Node address of 9 followed by 12 ASCII characters and a CRLF sequence. I received the response you see in **Screenshot 1**.

GO AHEAD ... PRESS THE BUTTON

The Data Burst Pushbutton on the VEmesh Node is programmed to send the hexadecimal state of the sending node's toggle switch array and a canned message to the Gateway. To test the operation of the Data Burst Pushbutton, we must put the Node into Standard mode. Nothing needs to be done to the Gateway. Placing the Node into Standard mode is accomplished by powering down the Node, setting the toggle switch array to address



■ **SCREENSHOT 1.** The VEmesh Node address (9) and my ASCII message were echoed by the VEmesh Node pictured in Photo 3.



■ **SCREENSHOT 2.** This message was transmitted by our VEmesh Node in Standard mode. The zero in the "alert message" indicates the state of the VEmesh Node's toggle switch array. Looks like somebody didn't run this through the old spell checker.

zero, and repowering the Node.

After powering up the Node in Standard mode, the VEmesh Node and Gateway activity LEDs resume their synchronous blinking cycles. Recall that the Gateway and Nodes in the network exchange data using predetermined timing. The blinking of the nodes' indicator LEDs is representative of the synchronized data exchanges. The

idea behind the Data Burst Pushbutton is to demonstrate how a node can break the data exchange sequence and send its message immediately. The Data Burst Pushbutton evaluation mode worked as designed as you can see in **Screenshot 2**. The zero preceding the colon in the canned message reflects the setting of the toggle switch array.

APPLYING VEMESH

The VEmesh technology was initially designed with remote utility meter reading and wireless sensor applications in mind. However, I can envision a sensor or group of sensors tethered to a microcontroller whose UART is tied to a VEmesh Node's RS-232 interface. Another thought that comes to mind is the incorporation of a microcontroller's analog-to-digital output into a VEmesh data message. Yet another good application of this wireless network is an alarm system in which monitor nodes can be added at will.

I'm sure you have some practical uses for a VEmesh wireless network. After all, it's now part of your Design Cycle. **NV**

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■ Fred Eady can be contacted via email at fred@edtp.com and the EDTP Electronics website at www.edtp.com.

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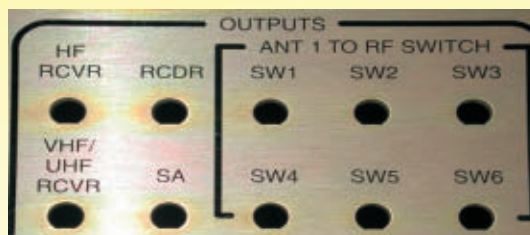
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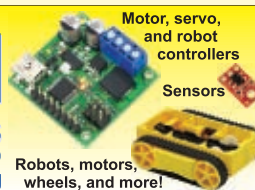


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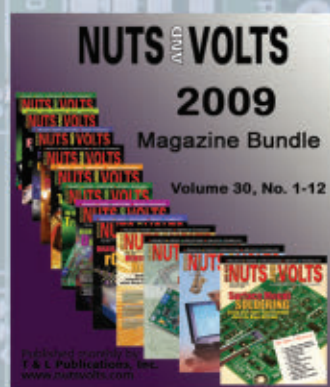
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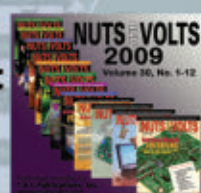
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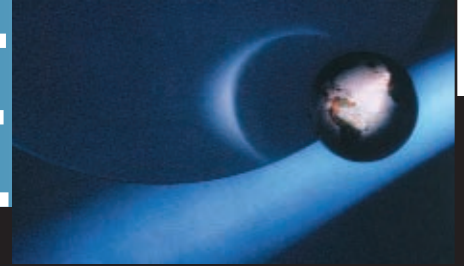


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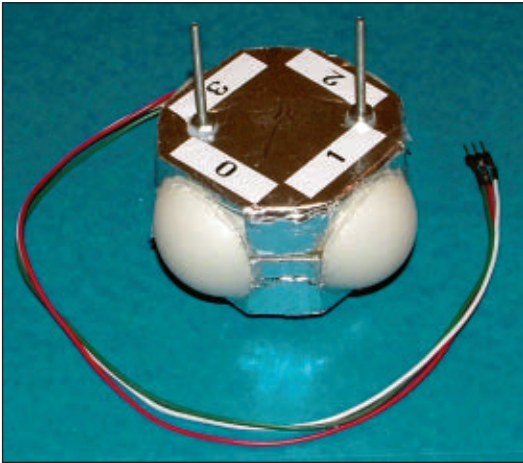
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■ BY L. PAUL VERHAGE

SUN SENSOR FOR DATA COLLECTION

During a weather balloon's ascent, its near spacecraft will spin unpredictably. This is acceptable if you want to observe in every possible direction, but it's not so great if the sun's position is important to the data you want to collect. The sun sensor presented here is just the ticket for data collection that's sun sensitive. So, this month's article discusses a design I developed for near space use.



Let's see what happens when a near spacecraft collects data without regard to the sun's position. The **three images below** were all taken at similar altitudes but at different sun angles. The **chart** on the next page is of the sky's brightness (in three different colors) and contains data collected throughout a near space mission.

During a typical near space mission, the near spacecraft rotates at an irregular speed and direction. The speed and direction is not predictable since many factors influence the balloon's rotation like changing wind speed and balloon shape. Normally, rotation is ignored and the flight computer collects data based on mission elapsed time or altitude. Data spikes are removed later (if possible) from the spreadsheet to smooth out the data. With the advent of digital cameras and large memory cards, near space missions record tremendous amounts of pictures to

work around the problem — if you take 200 photos, some of them are bound to be good.

However, I prefer to record data when the camera or sensor is pointed in the proper direction. The way to do this is to carry a sun sensor just like real spacecraft. Space-rated sun sensors are too heavy and complex, however, to justify their use on an amateur near space mission. Therefore, I developed a lightweight substitute. Its current software reports the sun's position in quadrants (90 degree units) which is good enough for many near space (and other robotic) uses.

THEORY OF OPERATION

The sun sensor takes advantage of the light sensitive properties of cadmium sulfide (CdS) cells (a.k.a.,

■ This image was taken when the camera was pointed towards the sun (the sun is located just above the right side of the picture). The sun's light brings out atmospheric layering but wipes out most of the details in the clouds.

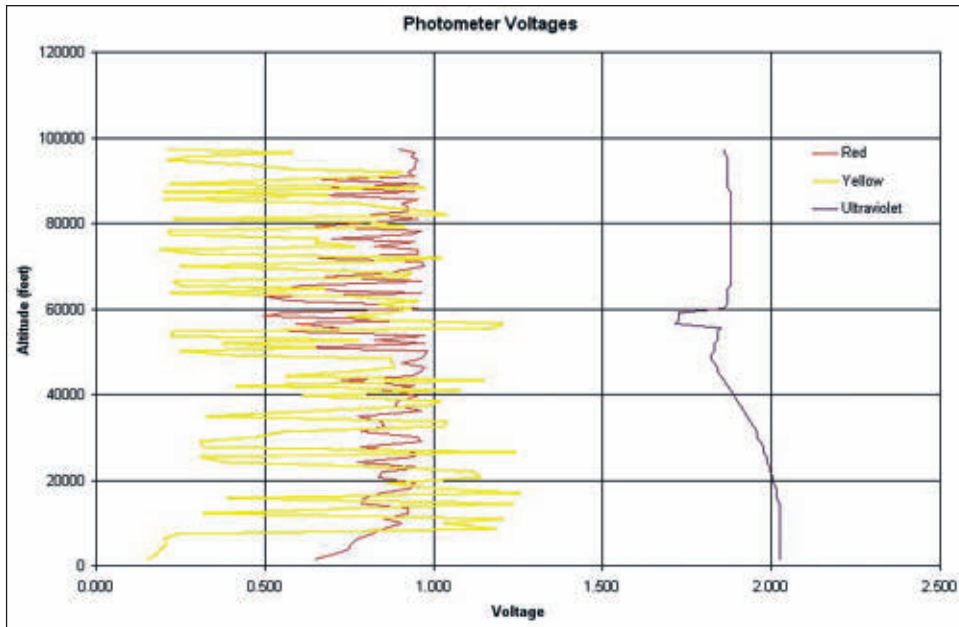


■ This image was taken when the camera was pointed away from the sun. Because the clouds hide most of their shadows, much of the cloud's shapes are not as apparent.



■ This image was taken when the sun was located 90 degrees away and out of the field of view. Cloud shapes and some structure to the atmosphere are apparent.





■ This chart should show a “smooth flow” in the photometer data. The spikes in the data (seen especially in yellow) are the result of the sky photometer collecting data when it was pointed towards the sun. The flight computer wasn’t aware of the sun’s position, so it collected readings at regular intervals.

READADC x, CHx

The PICAXE-14M uses two additional byte-size variables during the comparison of quadrant readings. The first is **VALUE** and it stores the largest current ADC reading. The second is **HEADING** and it stores the number of the quadrant with the currently greatest ADC reading.

After digitizing all four quadrant values, the PICAXE-14M

sets **VALUE** to the value in the variable **CH0** and **HEADING** to 0. Then, the remaining three ADC readings (in variables **CH1**, **CH2**, and **CH3**) are compared to **VALUE**. When a greater ADC reading is found, **VALUE** is set to the new ADC reading and **HEADING** is set to the quadrant of the ADC reading. By the end of the comparisons, the variable **HEADING** contains the quadrant with the greatest ADC reading (called the solar quadrant). The PICAXE then generates a serial message at 1200 baud with the following format:

H, Heading

Heading is a one byte digit from 0 to 3 that indicates the current solar quadrant. The PICAXE-14M repeats the process after sending the message so that at anytime during the mission, the flight computer can listen to reports on the current solar quadrant.

BUILDING THE NEARSYS SUN SENSOR

There are two major steps to building a sun sensor. The first is to construct the printed circuit board (PCB) and solder its components. The second is to construct the sensor housing. Let’s start with the soldering. You’ll need the following electronic components to make the NearSys Sun Sensor circuit:

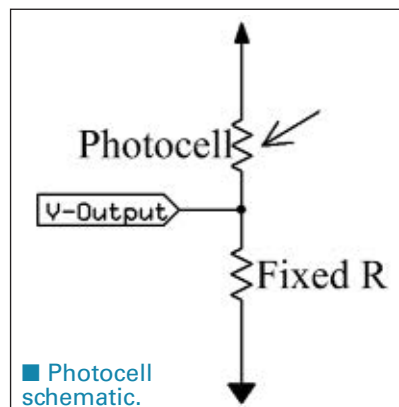
- PICAXE-14M
- 14-pin IC socket (300 mils wide)
- 10K resistor (1/4W)
- 22K resistor (1/4W)
- (2) three-pin straight male headers
- (4) CdS photocells
- (4) CdS-matching resistors (see directions for selecting these resistors)

photocells or photoresistors). Photons of light give electrons bound to the CdS molecule the energy they need to jump to another molecule. The more intense the light, the greater the energy available to the electrons, and the easier it is for them to make the jump. The easier it is for electrons to jump, the lower the resistance of CdS. Pairing a light sensitive resistor with a fixed resistor in a series circuit creates a light sensitive voltage divider; in other words, a circuit that produces a voltage related to light intensity.

With four light sensitive voltage dividers arranged in 90 degree arcs, the sun’s position (in one of those quadrants) can be determined by finding the highest voltage of the four voltage dividers. For that task, I selected the PICAXE-14M.

By default, the PICAXE-14M has five inputs on the left side of the IC (pins 3 through 7) and six outputs on the right (pins 8 through 13). However, only one of the inputs (input 4) is capable of analog-to-digital conversion (ADC). Fortunately, the **DIRSC** command allows the six portC I/O pins of the PICAXE-14M to be redefined. **DIRSC** is a bit level command with each bit representing the input/output state of each portC I/O pin. The NearSys Sun Sensor uses the command **LET DIRSC = %00110000** to convert portC pins 0 through 3 into inputs (capable of doing ADC), and pins 4 and 5 into outputs.

The PICAXE digitizes the voltages of the four light sensor circuits with the following command. In the example here, x is the ADC I/O pin being digitized and it ranges from 0 to 3. **CHx** is the name of the byte-size variables in RAM that the results of A-to-D conversions are stored in, and it ranges from **CH0** to **CH3**.



■ Photocell schematic.

■ This diagram is a guide to the proper placement of sun sensor components. Note that the PCB has four large holes (one in each quadrant) for mounting the PCB (these are not needed in most cases, so don't drill them out at this time). There are three smaller holes for the strain relief of the sun sensor's three-wire cable. A 1.5 mm diameter hole works well for these holes.

- #24 AWG stranded wire (three different colors are recommended)*
- Heat shrink tubing for #24 AWG wire
- NearSys Sun Sensor PCB
- NearSys Sun Sensor code
 - Download the PCB pattern and code from the *Nuts & Volts* website at www.nutsvolts.com.

* Use at least two foot long wires

SELECTING THE CDS-MATCHING RESISTORS

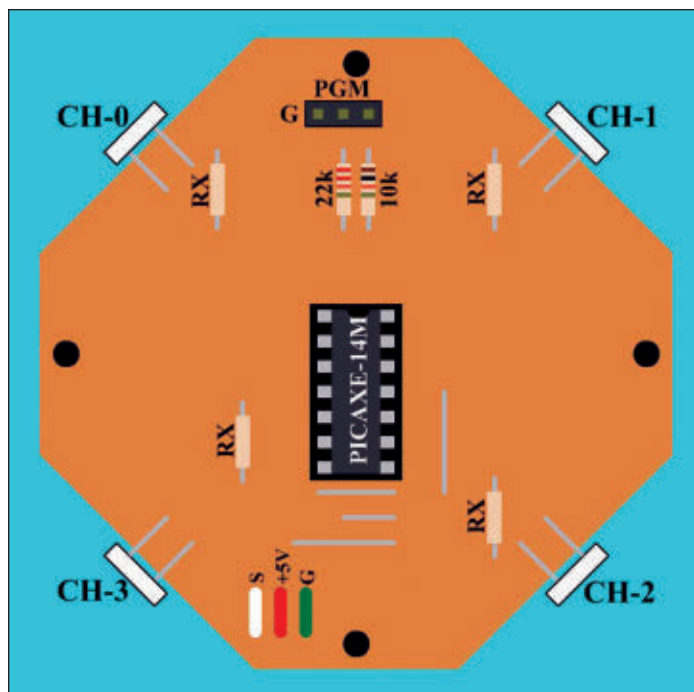
In order to make each sun sensor quadrant as sensitive to light variations as possible, we need the voltage swing of each photocell circuit to be as great as possible. We can find the best resistor for each photocell (its matching resistor) by using the following procedure:

- Measure the dark resistance of the photocell by pointing the photocell away from the sun (and pointed towards a dark surface). Call this value D.
- Measure the light resistance of the photocell by pointing the photocell towards the sun. Call this value L.
- Calculate the geometric mean of the D and L values with the equation below. If you're unfamiliar with a power of one-half, it means the square root. The closer the fixed resistor is to this calculated value, the greater the voltage swing of the photocell circuit.

$$M = (D * L)^{1/2}$$

After selecting the four CdS-matching resistors, you're ready to assemble your sun sensor PCB. There are four jumper wires in the sun sensor and the best wires for this purpose are cut resistor leads. So, form the leads of the resistors and solder them to the PCB. After cutting the leads, form the cut leads to make the jumper wires and solder them. Then, install the 14-pin IC socket and then a three-pin header. Bend the photocell leads to 90-degree angles where they can just hang over the edge of the PCB (see how the photocells are positioned in the **parts placement diagram**).

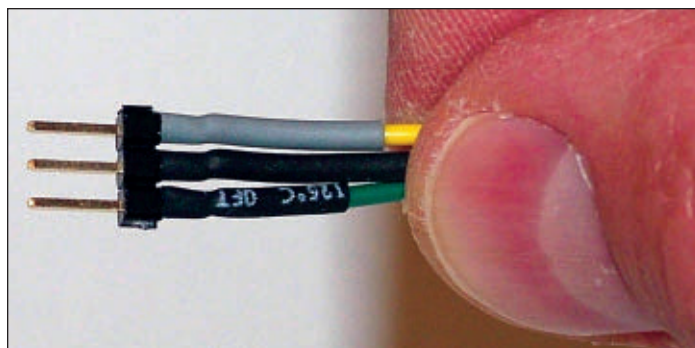
The next step is to create the sun sensor's power and signal cable. Strip 1/4" of insulation from one end of each of the three wires and solder them to the PCB. Then, pass each insulated wire through the strain relief hole next to its solder pad. The wires terminate with a three-pin male header, so strip 1/4" of insulation from the ends of the wires and tin them. Slide heat shrink tubing over the wires and push them away from the tinned ends. Place the long



end of the three-pin header into a receptacle (this keeps its three pins in their proper position during the soldering). Quickly tin the three short pins. Then, one at a time, place the wires in contact with the short side of the header pins, and quickly heat the tinned pin and wire with a soldering iron. After the solder cools, slide the heat shrink over the soldered connection and shrink (the proper order of the wires depends on the flight computer, but typically, they are ordered like the wires in a servo cable).

The last step is to test the sun sensor. First, check the bottom of the PCB for shorts. The rest of the test can be performed without the presence of the sun, as long as it's performed in a room that has a single light source. Plug the sun sensor's power and signal cable into a flight computer (or into a breadboard set up to provide five volts and ground). Start the PICAXE Editor and open the sun sensor code. In the code, comment out the SEROUT command and uncomment the DEBUG command. Plug the programming cable into the programming header of the sun sensor and download. After downloading, the PICAXE Editor's debug screen will open. Verify that the Heading variable (byte B5) is set to the sun sensor's solar

■ The completed header will look like this.



quadrant (that's the quadrant currently pointed towards the sun or room light). Next, rotate the sun sensor and verify that the Heading variable changes as a new quadrant rotates towards the sun (or light).

BUILDING THE SUN SENSOR BODY

The sun sensor shown at the beginning of this article has a two-piece shell housing. Both halves (the top and bottom half) are made of 1/2" thick Styrofoam and are covered in aluminum tape. Ten-millimeter thick Cellfoam 88 is another good material for making the sun sensor's housing. The top shell is essentially a lid while the bottom shell contains the sides of the sun sensor. The top and bottom shells are the same size octagons. The sides are tall enough to create a 1-1/2" tall housing and are hot-glued to the bottom shell.

The housing's four diffusers are cut from ping pong balls. Use a circle template to draw perfect 1-3/8" diameter circles on the balls. Cut the circles from the ping pong balls using cuticle scissors and an Exacto™ knife to make the starting hole. Make slightly smaller holes in the quadrants of the sun sensor, centered where the photocells can look out. Use the Exacto knife to cut out these circles.

Place the completed PCB inside the bottom shell and measure how high it needs to be raised to center the photocells in the center of the quadrant openings. Cut some Styrofoam spacers to that thickness and hot-glue them into the bottom of the shell. Hot-glue a little foam rubber to the inside of the top shell to keep the PCB firmly in place once the shells of the housing are closed. (Alternatively, you can hot-glue the PCB to the bottom shell housing.)

Before gluing the top to the sun sensor housing, cut a small opening in it just large enough for a programming header to reach the PCB inside. That way, the sun sensor firmware can be updated without having to take the housing apart.

Cover the shells with a single layer of aluminum duct tape. Cut a Styrofoam plug for the programmer opening in the top shell and tape the cover in place (you can always remove the tape to expose the plug and programming header). Before sandwiching the PCB between the shell

halves, mark the quadrants on the housing as 0, 1, 2, and 3 (the top silk pattern explains which quadrant is which). After labeling the quadrants, glue the shells together. Then, hot-glue the ping pong ball diffusers over the quadrant openings in the sun sensor.

To be effective, the sun sensor must be mounted on top of a module where it is in constant sunlight and never in the shadows. Therefore, I made a Styrofoam bracket to fit the top of a near spacecraft module. The bracket has two Popsicle sticks glued to it where the sun sensor attaches with a rubber band. The bracket and sun sensor are held to the module with additional rubber bands wrapped around the module's hatch. Rubber bands are sufficient to mount the sun sensor since it and the bracket weigh so little.

READING NEARSYS SUN SENSOR DATA

A flight computer using the sun sensor uses the following code to read solar quadrant reports. This example was written for a BalloonSat Mini flight computer that had the sun sensor plugged into I/O port 4.

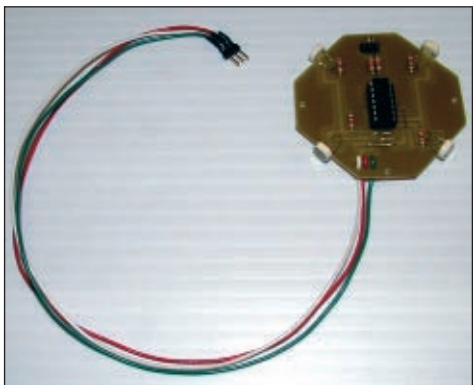
```
SYMBOL Heading = B1
Sun:
SERIN 4, T1200_4, ("H"), #Heading
```

The desired value of the Heading variable depends on where the camera or sensor are pointed. Since the quadrants are marked on the sun sensor housing, it's easy to tell the proper heading and to code it into the flight computer's program. The subroutine operating the camera or sensor uses an IF/THEN routine to decide if a picture should be taken or if data should be collected at that moment.

That's it for making a nearsys sun sensor. Next time, I'll update you with tests of the sun sensor's capabilities and discuss an ultraviolet addition to my environmental test chamber.

Onwards and Upwards,
Your near space guide **NV**

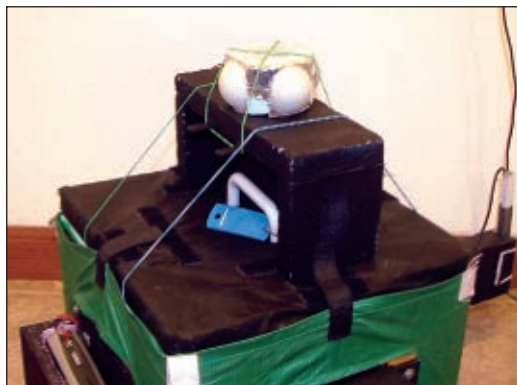
■ The completed PCB.



■ The sun sensor bracket.



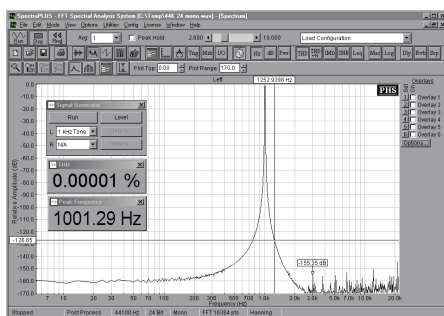
■ The completed sun sensor firmly attached to its mounting bracket.



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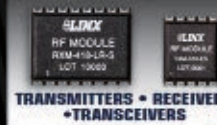
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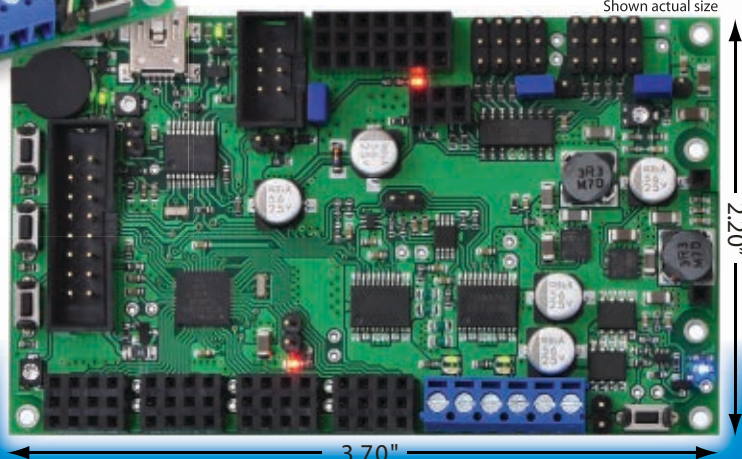


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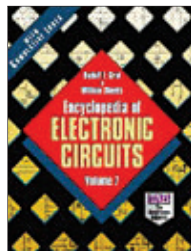


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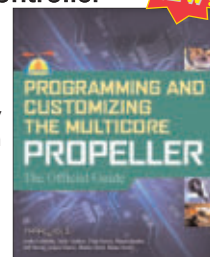
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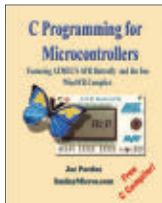
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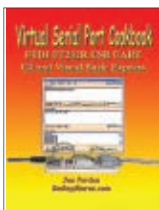


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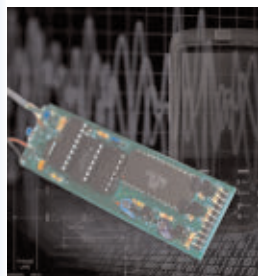
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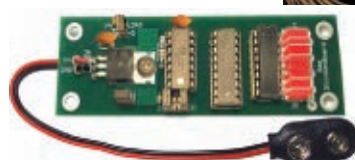
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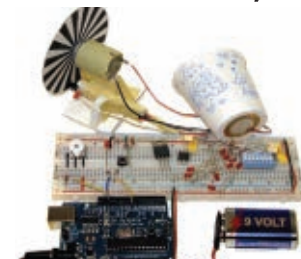
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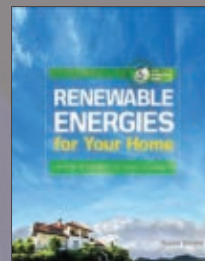
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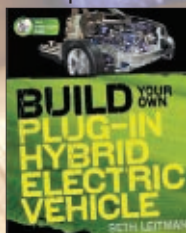
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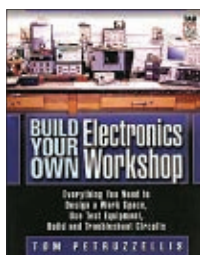
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FEEDBACK continued from page 11


Let's face it. Science dictates that when things get old, they wear out (decay). Rubber gets brittle, magnets get weaker, and so on. Things almost never get better with age.

I had an acquaintance who worked at the high-end stereo shop in town back in the '90s. They sold amplifiers in the \$5,000 to \$10,000 range. For a mere additional \$300 to \$500, they would apply custom modifications to your new purchase. They would replace the power cord with one that had larger diameter wire, replace the filter capacitors with ones of larger value, and replace the bridge rectifier with one that had a larger current capacity. He told me, of course, that increasing these values would improve the amplifier's response on peaks by reducing drop-off of the supply voltage. All true statements, technically.

I asked him about these amplifiers and he said they were the finest amplifiers on the planet made by the finest companies in the business. So I asked him, "Are you telling me that the finest companies in the business are making products with substandard line cords and inadequately sized power supply components? This contradicts your statement that these are the finest amplifiers on the planet." He said they

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became the finest when the custom mods were applied. Snake oil! When I told him the brand of components I used, he said "Oh that's not Hi-Fi. You have Mid-Fi!" Ha! A little knowledge is sometimes worse than none at all.

While the mods may deliver an improvement it is unlikely the human ear could hear it. It's possible even instruments could not detect it. You would assume a high-end amp had adequately sized components by design.

Unless you perform a strict double-blind listening test, you can never assume that an improvement is real. You know, put a blindfold on your eyes and put the component behind a screen. You are not even allowed to see the size of the speaker cabinet, the company logo, or any other details such as the size or color of the wire. This is so your mind is not tricked into selecting the bigger cabinet since bigger is always better, right? You can't go wrong with science.

Rick Swenton

>>> QUESTIONS

LCD TV Displays

I have a Casio portable color LCD TV (handheld) that has been made obsolete by the new digital signals.

I would like to use the display in an upcoming project.

Can anyone direct me to where I could find information on driving color displays with a microprocessor?

#3101 TJ Treinen
Oklahoma City, OK

Convert Old Record Player To Record To USB

I have experience programming, soldering small projects, and wiring. I've built my own computer from parts. I have a stack of records from the '50s, '60s, and '70s, and two record players (never tossed the old electronics). I saw a device in a store that would record your records to USB. Can't I build my own? Any suggestions?

#3102 Sunny Russell
Kenosha, WI

Experiments With An AC Alternator

I have been experimenting with a 10,000 watt AC alternator. This is the kind that is usually called a generator that outputs 110/220 VAC for use as a backup power source. Although I have had a good deal of experience with electricity and electronics, I have yet to find a good explanation of how this type of alternator actually works. Every source I can find on alternators deals with automotive alternators which I assume are similar.

I have an application where I am using the variable speed from the gas engine that turns the alternator to create a variable AC voltage output. I know an alternator of this type has no permanent magnet so it needs to get up to some RPM before it generates ANY voltage at all. On mine, this kicks in somewhere between 35 and

50 volts AC.

Can someone explain how this type of AC power alternator actually works and do you think it is possible to excite the fields externally so the output voltage kicks in more consistently at low RPM?

#3103 Greg McMurry
Pacific Palisades, CA

DC Electric Motor

How does one find the wattage of a 24 VDC motor that has no name plate? I want to purchase a speed control for my electric bike, but they all want to know the wattage of the motor.

#3104 Frank Whelan
Lompoc, CA

Dimmers

What is the difference between an ordinary light dimmer and a ceiling fan speed controller? They look the same except one is twice the price.

#3105 Terry Stine
Peoria, AZ

PIC Generated Voltage

How can I use a PIC controller to generate the required voltage in a DC/DC converter with an LCD display or USB communication with a laptop?

#3106 Cornelius
via email

Anemometer Circuit

I'm looking for an anemometer circuit using the cooling effect on transistors. I found some on the Internet but they typically only measure low (<2 mph) wind speeds. A circuit with an analog output I can interface to a microcontroller would be great as I plan to add other sensors. Mechanical

anemometers need to be calibrated which I'd like to avoid (and I'd rather build a circuit anyway).

I need an anemometer to measure "normal" wind speeds (up to maybe 50 mph). I'd like to install a wind mill next year to assist in powering my house but I want to log the wind speeds and frequency to determine if it's worthwhile installing the windmill.

#3107 Dave Berkebile
Wilton, NH

Stereo Headphone Volume Control And Left-Right Reversing

I want to build a stereo headphone control box for a home recording studio monitoring setup. It can be passive or active, but if it is active, it must have high quality circuitry, as should all the other components. It needs to have left and right channel volume controls, plus a low-noise switch (leaf switch?) to reverse the left and right channels so that I can quickly change the signals between left and right channels without removing the headphones. Can anyone offer a schematic and parts list?

#3108 Starliner
Preston, MD

>>> ANSWERS

[#10092 - October 2009] Flashing LEDs

I need a parts list and schematic to create flashing lights on small scale emergency vehicles to be used on a slot car racing layout.

#1 Figure 1 is a schematic using the venerable NE555 timer to simulate

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flashing emergency lights. The resistors R3 and R4 control the rate of charge while the discharging capacitor facilitates the switching between the red and blue LED.

Play with the capacitor value and the R3/R4 resistors to fine-tune the flashing oscillations. I think diffused LEDs would make a better effect than the clear ones I used, but I just had them laying around.

The NE555 is small (the LEDs are bigger, so hopefully you can get it to fit in your design).

See the circuit in action at www.youtube.com/watch?v=o-ljVi3VGgE

Gian James
Boulder, CO

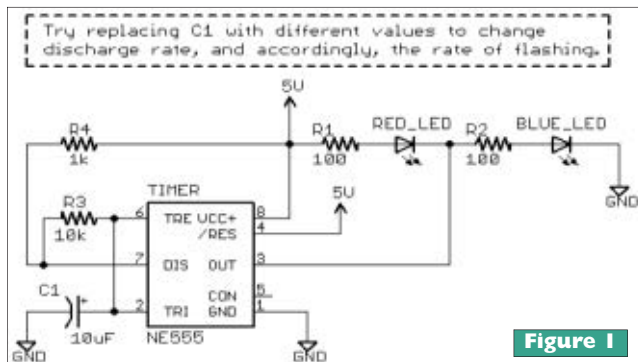
#2 Try using simple 3-5 VDC flashing LED[s]. Connecting two small-sized coin batteries together will provide a fairly long continuous life cycle. They can be purchased from vendors such as www.all-electronics.com.

They have an excellent supply of T1-3/4 and T-1 sizes in four colors.

John Mastromoro
Saint Johnsville, NY

[#11093 - November 2009] **Bridge Rectifier Voltage Readings**

Why, when I read the open circuit DC voltage with both sides of the output disconnected from the rectifier, I read the input voltage $\pm 10\%$?



However, if I reconnect the load – a 90 VDC brake – and have the output switching device open, the measured DC output voltage at the rectifier is approximately 30% greater than the disconnected output voltage.

The most likely explanation is that you have a capacitive load on the rectifier output when you are measuring the higher output voltage. You should measure $1.414 (\sqrt{2})$ times the input voltage minus diode drops with a well working peak rectifier. Since you are measuring close to this value, this is probably the culprit.

Walter Heissenberger
Hancock, NH

[#11094 - November 2009] **Vehicle ECU Programming**

I would like to know what kind of programming is used in a car ECU. Is it C, C++, Visual Basic, or something else?

Probably binary code. Computers speak binary. The translation from compiler language to binary is performed in the design lab and then released to production as a binary file.

Peter Goodwin
Rockport, MA

[#11096 - November 2009] **Wireless HVAC Fan Controller**

I want to install a duct fan in my HVAC system. But the duct where the fan will go is in the attic and the main airhandler is in the basement. The fan runs on 120 VAC and pulls 2A. I need an affordable wireless system that would turn the duct fan on and

off when the main airhandler turns on and off.

#1 Assuming you simply do not want to run a control wire between the auxiliary fan and the air handler, here's a solution.

X10 powerline control has been around for a long time. It's an old technology but in most cases will work just fine. You can get an X10 powerflash module PSC01 to plug into an outlet near the air handler. This device accepts a dry contact closure of up to 18 volts AC or DC on the control input. You could wire in your 24 VAC air handler fan control signal through a voltage divider to drop the voltage below 18V, or you could mount a vane switch inside the air path of the air handler. A vane switch is a small sensitive microswitch (one that requires very little pressure to operate the switch); install a sail on the switch lever. The sail is nothing more than a piece of lightweight thin cardboard or similar material. When the air "blows on the sail," the switch will click on. Either of these methods will cause the PSC01 to send an X10 command into the AC power line. At the other end, get an X10 appliance module AM466 and just plug the auxiliary fan motor into the module. The advantage of the vane switch is that your HVAC technician won't accuse you of causing problems with the system. But it's mechanical and more prone to failure than a direct connection.

Set the house code and unit code the same on both X10 units. Set the switches on the PSC01 to Mode 3 (only transmits a single house/unit code, on/off). Set to Mode A for up to 18 VAC or DC control input or Mode B for dry contact control.

Of course, one side effect with the older X10 technology is that your

neighbor might be using X10 too. If his house is close enough and on the same pole transformer, you could receive his signals. Just change to a house/unit code that he is not using.

Rick Swenton
via email

#2 I don't have the total solution, but an idea to start with. Rather than designing the wireless transmitter/receiver portion, one pre-existing solution you can piggyback off of is a wireless doorbell system you can get at the hardware store for less than \$20. You can easily test if it will transmit through the floors.

You can replace the transmitter (doorbell button) battery with a cheap power brick to avoid changing batteries. You also need it for the rest of the circuitry to sense the air handler state and fire a relay to close the "button."

Then, you tap into the circuitry of the receiver/ringer to get the ringing signal to then pulse a relay circuit to start/stop the fan.

I have done something similar, and having a reliable wireless system to start with was boon to the project.

Pete Lunt,
Fairfax, VA

[#11097 - November 2009] Power Outage Monitor

From time to time, I experience power outages when I am not at home. I would like to either build or purchase a device which connects to the AC power line and begins timing when the AC power drops and stops timing when the AC power is restored. The readout must indicate the time elapsed during the outage.

#1 I like simple solutions to problems. I suggest that you obtain a common electric clock — the old-fashioned kind that contains a synchronous motor. Set the clock to the time of day. If power fails, the clock will lose time. Subtract the time indicated from the current value to obtain the duration of the power outage.

Peter Goodwin
Rockport, MA

#2 The simplest solution would be to have a 'normal' elapsed time meter that you then read and subtract from actual elapsed time.

That's not very user friendly, though, so I'd say get a 12 VDC 'running time' meter (do a Google search for 'elapsed time meter' and you should have NO problem there) and connect it through the NC contacts on a 120 VAC relay to a 12V battery. Plug the coil of the 120V relay into any handy outlet. Keep the battery charged any way you like.

When the power is on, the NC contacts will be open, turning the running time meter off.

When power goes off, the NC contacts close, making the meter run.

Rusty Carruth
Tempe, AZ

#3 When I was working, we had an APC UPS RM1500 that came with the software and cable to be able to interrogate it for its logs. It kept that kind of info for power outages and also surges and sags.

It may work for you.

Jim Russell
London, KY

[#11098 - November 2009] Labeling Items

Can someone recommend the best way to put professional-looking text labels on a project enclosure, at a hobbyist price point? I've been using Brother P-Touch labels; while cheap, they don't have the visual impact that I'd like to have and don't work well in constrained spaces.

#1 I used inexpensive dry transfer (rub-off) letters for a recent project, and was happy with the results shown in **Photo 1**.

I suggest you use masking tape to align the letters. Use a dull pencil to gently transfer every corner of each letter to your box; then press harder through a paper burnishing sheet to lock the letters down if you are happy with the results (or, use a hobby knife to gently scrape a letter off if you need to make a change).



Photo 1 Search for "dry transfer;" they offer sheets in a wide variety of colors, sizes, and fonts.

(Be aware that letters and numbers usually come on separate sheets.)

Richard Carlson
Fort Collins, CO

#2 I had this same problem with my mistralXG project (see N&V Feb/Mar 2009). After the article was published, I found a suitable Hammond case to use as an enclosure, but didn't want to resort to simple labels. I also wanted to add a logo to the case. After examining several alternatives — all too expensive — I found some vinyl printer stock that did the job. The vinyl has a special coating that takes inkjet ink very well and has a paper backing that reveals a sticky side when peeled off. The results were better than I hoped (**Photo 2**). You can see the results at www.grapevyne.com/pic.projects. I found a supplier on eBay who sold me a small pack (10 sheets or so) for a few dollars.

Steve Russell
Winchester, UK

Photo 2





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| X-Y | Yes | | |
| Autoset | Yes (30Hz~40MHz) | Yes (30Hz to 60MHz) | Yes (30Hz to 200MHz) |
| EXT. input | Yes | | |
| Trigger Mode | Auto / Normal / Single | | |
| Trigger Slope | +/- | | |
| Trigger Level Adj. | Yes | | |
| Trigger Type | Rising edge / Falling Edge | | |
| Trigger Source | Ch1 / Ch2 / EXT | | |
| Pre/Post trigger | 0-100% | | |
| Buffer size | 10K-32K per ch | | 10K-512KB per ch |
| Shot Bandwidth | DC to 40MHz | DC to 60MHz | 100MHz |
| Max Sample Rate | 100MS/s | 150MS/s | 250MS/s |
| Sampling Selection | Yes | | |
| Waveform Display | port/line, waveform average, persistence, intensity | | |
| Network | open / close | | |
| Vertical Mode | Ch1, Ch2, Dual, Add | | |
| Cursor/Measurement | Yes | | |
| Spectrum Analyzer | | | |
| Channels | 2 Channels | | |
| Math | FFT, addition, subtraction, multiplication, division. | | |
| Bandwidth | 40 MHz | 60 MHz | 200 MHz |
| Cursor | Frequency, Voltage | | |
| Data Samples | 10K-32K/Ch | | 10K-1M/Ch |

60MHz Hand Held Scopemeter with Oscilloscope & DMM Functions

Who Says

you can't take it with you?

With the DSO1060 YOU CAN!



- * 60MHz Handheld Digital Scopemeter with integrated Digital Multimeter Support
- * 60MHz Bandwidth with 2 Channels
- * 150MSa/s Real-Time Sampling Rate
- * 50Gsa/s Equivalent-Time Sampling Rate
- * 6,000-Count DMM resolution with AC/DC at 600V/800V, 10A
- * Large 5.7 inch TFT Color LCD Display
- * USB Host/Device 2.0 full-speed interface connectivity
- * Multi Language Support
- * Battery Power Operation (Installed)

Item #
DSO1060



\$569.00



Your Power Supply Headquarters!!

We carry a LARGE selection of power supplies from bench top to variacs to single, dual and triple output to wall plug AC adapters to large and ultra large regulated power supplies.

Adjustable DC Power Supplies with Adjustable Current Limiting



Regulated linear power supplies with adjustable current limiting. The LED display shows both Volts & Amps. The current output can be preset by the user via a front panel screwdriver adjustment screw while the voltage is adjustable by a front panel multi-turn knob for precise voltage settings. Output is by front panel banana jacks and there is also a covered terminal strip for remote voltmeter sensing at the load.

- * Utilizes SMD technology
- * Pre-Settable Voltage & Current levels
- * Front Panel On/Off Switch
- * Large LED readout for Voltage & Current
- * S+ & S- Sampling terminals

| | | |
|---------------------------|--------------|----------|
| 0-30 Volt / 0-10 Amp Adj. | (CSI3010X) | \$198.00 |
| 0-30 Volt / 0-20 Amp Adj. | (CSI3020X) | \$299.00 |
| 0-40 Volt / 0-10 Amp Adj. | (CSI4010X) | \$269.00 |
| 0-60 Volt / 0-10 Amp Adj. | (CSI6010X) | \$319.00 |
| 0-30 Volt / 0-10 Amp Adj. | (CSI3010X) | \$198.00 |
| 0-120 Volt / 0-3 Amp Adj. | (CSI120030X) | \$265.95 |

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Energy Saving Variacs



These adjustable Variacs from CircuitSpecialists are VERY popular. They can be used in science labs, by audiophiles (Great for old Tube Amplifiers), hobbyists, in film & video lighting applications. Units are adjustable from 0-130Volts

| | | |
|-------|--------------|----------|
| 5Amp | (TDGC2-0.5) | \$49.95 |
| 20Amp | (TDGC2-2) | \$104.00 |
| 30Amp | (TDGC2-3KVA) | \$119.00 |

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HengFu Switching Power Supplies



Circuit Specialists carries a wide selection of HengFu switching power supplies. All models have overload, over voltage, over temperature & short circuit protection.

Hi-Power Enclosed Single Output

| Item # | 1+ | 10+ |
|-------------------------------|----------|----------|
| 1000W 12v/84A (HF1000W-SM-12) | \$299.00 | |
| 1000W 24v/42A (HF1000W-SM-24) | \$299.00 | |
| 700W 48V/15A (HF700W-S-48) | \$189.00 | \$174.00 |
| 500W 48V/11A (HF500W-S-48) | \$119.00 | |
| 500W 24V/21A (HF500W-S-24) | \$169.00 | \$149.00 |
| 500W 12V/42A (HF500W-S-12) | \$169.00 | \$149.00 |
| 300W 48V/6.3A (HF300W-S-48) | \$69.00 | \$61.00 |
| 300W 36V/8.5A (HF300W-S-36) | \$69.00 | \$61.00 |
| 300W 24V/12.5A (HF300W-S-24) | \$69.00 | \$61.00 |
| 300W 12V/25A (HF300W-S-12) | \$69.00 | \$61.00 |
| 300W 9V/33A (HF300W-S-9) | \$69.00 | \$61.00 |
| 300W 5V/60A (HF300W-S-5) | \$69.00 | \$61.00 |

Open Frame Single Output

| Item # | 1+ | 10+ |
|------------------------------|---------|---------|
| 15W 5V/3A (HF15W-SPL-5) | \$15.99 | \$13.59 |
| 15W 12V/1.3A (HF15W-SPL-12) | \$15.99 | \$13.59 |
| 15W 24V/0.85A (HF15W-SPL-24) | \$15.99 | \$13.59 |
| 15W 48V/0.32A (HF15W-SPL-48) | \$15.99 | \$13.59 |

Enclosed Dual Output

| Item # | 1+ | 10+ |
|-------------------------------|---------|---------|
| 5V/10A-12V/4A (HF100W-DF-A) | \$39.00 | \$34.88 |
| 5V/15A-15V/2A (HF100W-DF-B) | \$39.00 | \$34.88 |
| 5V/24A-24V/1A (HF100W-DF-V) | \$39.00 | \$34.88 |
| 5V/1A-5V1.8A (HF10W-DL-A) | \$15.95 | \$13.79 |
| 5V/1.8A-12V/0.5A (HF10W-DL-B) | \$15.95 | \$13.79 |
| 5V/1.8A-15V/0.5A (HF10W-DL-C) | \$15.95 | \$13.79 |
| 5V/1.8A-24V/0.3A (HF10W-FL-D) | \$15.95 | \$13.79 |

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POTRANS [Special Purchase]

150Watt 24V/6.5A Switchable Power Supply

- * High efficiency
- * High reliability
- * Protection: Over-voltage/Over-current/Over-power/Short-circuit
- * Output reverse protection
- * VAC input range selected by switch
- * 100% full load burn-in test
- * EMI/RFI: FCC Part 15J, Class A & CISPR 22 Class A



Item # CSI-15024-1M

1+\$19.00 10+\$14.95 100+\$12.95

UL, cUL, CCC, CE & TUV approved

Programmable DC Power Supplies

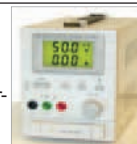
- Up to 10 settings stored in memory
- Optional RS-232, USB, RS-485 adapters
- May be used in series or parallel modes with additional supplies.
- Low output ripple & noise
- LCD display with backlight
- High resolution at 1mV



| Model | CSI3644A | CSI3645A | CSI3646A |
|-------------|----------|----------|----------|
| DC Voltage | 0-18V | 0-36V | 0-72V |
| DC Current | 5A | 3A | 1.5A |
| Power (max) | 90W | 108W | 108W |
| Price | \$199.00 | \$199.00 | \$199.00 |

Dual Output DC Bench Power Supplies

High stability digital read-out bench power supplies featuring constant voltage & current outputs. Short-circuit & current limiting protection is provided. SMT PC boards and a built-in cooling fan help ensure reliable performance & long life. All 3 Models have a 1A/5VDC Fixed Output on the rear panel.



| Item #: | Price 1+ | Price 5+ |
|--------------------------|----------|----------|
| CSI3003X-5 0-30V/0-3A | \$119.00 | \$112.00 |
| CSI5003X5 0-50V/0-3A | \$127.00 | \$119.00 |
| CSI3005X5 0-30V/0-5A | \$129.00 | \$122.00 |

Triple Output DC Bench Power Supplies

- Output: 0-30VDC x 2 @ 3 or 5 Amps & 1 fixed output @ 5VDC@3A
- Stepped Current: 30mA +/- 1mA



| Item #: | Price 1+ | Price 5+ |
|---------------------------|----------|----------|
| CSI3003X3 0-30Vx2@3A | \$198.00 | \$193.00 |
| CSI3005XIII 0-30Vx2@5A | \$259.00 | \$244.00 |

0-30V / 0-5A . DC Power Supply



The CSI530S is a regulated DC power supply which you can adjust the current and the voltage continuously. An LED display is used to show the current and voltage values. The output terminals are safe 4mm banana jacks. This power supply can be used in electronic circuits such as operational amplifiers, digital logic circuits and so on. Users include researchers, technicians, teachers and electronics enthusiasts. A 3 1/2 digit LED is used to display the voltage and current values.

www.circuitspecialists.com/csi530s

Item # **CSI530S** \$79.00

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The **Digi XBee 802.15.4 modules** are the easiest-to-use, most reliable and cost-effective RF devices we've experienced. The XBee modules provide two friendly modes of communication – a simple serial method of transmit/receive or a framed mode providing advanced features. XBees are ready to use out of the package, or they can be configured through the X-CTU utility or from your microcontroller. These modules can communicate point to point, from one point to a PC, or in a mesh network. Picking the right XBee module is best accomplished by choosing an antenna style (chip or wire) and power level (2 mW for up to 300 feet and 60 mW for up to 1 mile).

Digi XBee 802.15.4 modules

| Power Level | 2 mW | 2 mW | 60 mW | 60 mW |
|--------------|---------|---------|---------|---------|
| Antenna | Chip | Wire | Chip | Wire |
| Price | \$19.00 | \$19.00 | \$32.00 | \$32.00 |
| Stock Code # | #32404 | #32405 | #32406 | #32407 |

XBee modules may be used with our XBee adapters and the multicore Propeller chip (3.3 V). Non 3.3 V microcontrollers like the BASIC Stamp will need a 3.3 V power supply and signal buffer chip for communication to the XBee module.

Because the XBee modules have 2 mm pin spacing, we recommend one of our adapter boards for each module. Our adapter boards provide several advantages to the XBee modules such breadboard-friendly standard 0.1 inch pin spacing, mounting holes, and easy-to-solder connections. Even if you are communicating point-to-point without a PC, we still recommend that you always have at least one XBee USB Adapter (#32400; \$24.99) so you can easily configure and test each XBee module prior to putting it in a point-to-point application. Also, always have at least one of our affordable XBee Adapter Boards (#32403; \$2.99) for each XBee module you purchase.



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